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DEVELOPMENT OF SEED TREATMENTS FOR THE CONTROL OF BARLEY STRIPE[1]

C. S. REDDY AND L. C. BURNETT

INTRODUCTION

The production of barley in Iowa in 1928 (27,000,000 bus.) was nearly double that of any previous year in spite of a 12 per cent loss due to barley scab and stripe. These diseases constitute serious limiting factors to successful barley production in the State. On the successful solving of this problem may depend the choice of varieties, the time of sowing, nature of fertilizer used, and the crop rotation to be followed in order to secure the most satisfactory crop returns.

The control of barley stripe (*Helminthosporium gramineum* Rabh.) may be attempted along several lines such as: (1) The selection of resistant varieties or the development of resistant strains from some commercial variety, (2) late planting in warm soils, (3) obtaining seed from regions that are known to be free from the disease, and (4) treatment of home-grown seed with some disinfectant that will control the pathogene. The first method necessitates a long-time investigation unless some variety already established is found to be resistant. The second is inadvisable for the agronomic reasons that yields are decreased and scab and rust favored by late planting. The third method involves inspection of seed in large amounts, which is a laborious and costly practice. In the fourth method, seed treatment permits the utilization of our own seed stocks, and is a desirable immediate control measure, providing we have at hand a satisfactory fungicide.

In considering seed treatment as a control measure for barley stripe, these points in the development of the disease stand out: (1) a diseased seed looks healthy, but (2) it develops into a diseased plant which rarely produces seed; (3) spores from the diseased plant go to healthy barley heads with newly forming kernels; and (4) the fungus lives over winter in the apparently normal seed from these heads.

Barley stripe is a disease particularly adapted to control by seed treatment. This is true because no plants are injured in yielding capacity ex-

[1] Published with the approval of the Director of the Iowa Agricultural Experiment Station, Ames, Iowa.

cept those grown from infected seed. Diseased plants from infected seed are almost a total loss, seldom producing seed. Therefore, if the primary and ultimately systemic infection in the seed could be inhibited or the mycelium actually killed, serious losses to the ensuing barley crop by stripe would be prevented.

Seed treatment also controls covered smut of barley but for the most part affects only indirectly such diseases as scab and rust. A good seed treatment should not injure the seed and should be inexpensive in cost of material and of labor involved in making the treatment. Of the liquid treatments, formaldehyde has shown promise, but soaking the seed is objectionable. Some progress has been made in developing dry treatments for these diseases. Rodenhiser (6) found certain dusts that were effective but was unable to obtain yield data. Leukel, Dickson, and Johnson (2, 3, and 4) recently have reviewed the literature dealing with the control of barley stripe and have mentioned the effect of dust seed treatments on yields.

This paper presents the results of studies wherein attempts have been made to devise a dust fungicide that would effectively control barley stripe and covered smut. The purpose of this paper is to show the possibility of developing good dust fungicides for the control of these diseases and to show why adequate yield data are necessary before general recommendations should be made for barley seed treatment.

LOSSES IN IOWA FROM STRIPE AND OTHER DISEASES OF BARLEY

Estimates of losses from barley stripe and other diseases in Iowa, recorded each year since 1906, are on file in the Plant Pathology Section, Iowa Agricultural Experiment Station. On the basis of averages compiled from these data, it would appear that five important diseases occur on barley in Iowa, namely, stem rust, stripe, loose smut, scab, and covered smut.

Losses reported for stem rust, *Puccinia graminis* Pers., on barley averaged 3.5 per cent, but the average loss for the past five years (1924–1928) was only 1.0 per cent. The decrease may indicate that barberry eradication as a control measure has reached a stage where it has an effect on the prevalence of this disease. There were exceptional occurrences of this disease in 1907 and 1920, when the barley crop was injured to the extent of 20.0 and 17.0 per cent, respectively.

Following stem rust, the next highest average loss, 2.7 per cent, was from stripe caused by *Helminthosporium gramineum*. This disease is not decreasing. The average loss for the past five years (1924–1928) was 3.3 per cent. Survey notes by I. E. Melhus, in 1921, state that losses caused

by stripe have been much underestimated. Data on the occurrence of stripe in our 1927 and 1929 barley-variety plots are presented in table 1. These percentages are based on actual counts.

TABLE 1.—*Occurrence of stripe plants in barley varieties grown at Mason City, Iowa, 1927, and Ames, Iowa, 1929*

Varieties	Per cent stripe plants		Varieties	Per cent stripe plants	
	1927	1929		1927	1929
Horn	0	0.25	Manchuria (Minn. 184)	1.3	2.38
Featherston	tr.	2.5	Velvet (Minn. 477)	1.3	0.94
Bonami	tr.	1.56	Alpha	2.0	3.19
Sandrel	tr.	0.56	Colsess	2.0	1.81
Trebi (C. I. 936)	tr.	0.06	Caucasian	10.0	.....
Oderbrucker (Wis. 5–1)	tr.	8.00	Manchuria (Iowa)	16.0	.....
Ontario No. 21	0.6	1.25	Minsturdi (Minn. 439)	27.0	7.69
Hero	0.6	0.31	Minsturdi	46.0	10.88
Black Hulless	0.6	0.06	Glabron	.....	1.38
Trebi (Colo.)	0.6	.....	Wisconsin Barbless	.....	0.94
			Nepal	.....	0

I. E. Melhus has collected data on the occurrence of barley stripe at Ames, Iowa, during the five-year period 1917 to 1921. With his permission a summary of these data is presented in table 2.

TABLE 2.—*Occurrence of stripe in three classes of six-row barleys grown near Ames, Iowa, 1917–1921*

Classification	Per cent stripe plants					Average
	1917	1918	1919	1920	1921	
Caucasian	10.6	6.4	2.7	9.0	11.9	8.1
Oderbrucker	5.2	3.9	1.0	4.6	10.3	5.2
Manchuria	4.7	3.4	0.3	3.9	5.7	3.6

In table 2 the percentage of stripe plants in each case is the average occurrence in several selections from that variety. The data in this table indicate that more stripe normally occurs in Caucasian than in Oderbrucker and less in Manchurian.

Loose smut, *Ustilago nuda* (Jens.) Kell. & Sw., causes an annual loss in Iowa of 1.6 per cent, but the average loss for 1924–1928 was only 0.7 per cent. The average loss each year from this disease is never high, but the consistency of its occurrence makes it an important disease of barley.

TABLE 3.—*Number of heads affected with loose smut in four rod-rows of each of eighteen varieties of barley and the approximate percentage of loose smut by varieties and by seed treatments, Ames, Iowa, 1929*

Variety	Check	Check	Ethyl Iodide	Ceresan	Bar 3	Bar 4	Pa. 10	Bow	$NaHSO_3$	Check	Check	Total number smutted heads	Approximate Pct.
Wisc. Barbless	21	22	13	5	8	8	4	6	13	10	18	128	0.7
Bonami	11	5	2	5	1	0	2	1	0	2	3	32	0.2
Oderbrucker (Wis. 5–1)	11	8	4	1	3	3	1	0	4	1	6	42	0.2
Featherston	8	9	7	5	3	3	3	6	6	5	5	60	0.3
OAC 21	1	1	0	0	0	0	0	0	2	2	1	7	0.0
Trebi	6	4	4	0	3	5	0	1	2	8	5	38	0.2
Sandrel	4	1	7	3	3	0	1	1	1	6	4	31	0.2
Horn	6	13	15	5	6	10	0	6	10	13	12	96	0.5
Velvet	8	6	6	5	4	7	7	6	9	9	6	73	0.4
Glabron	81	82	91	97	84	99	86	87	102	86	87	982	5.6
Spartan	24	14	12	14	28	14	12	14	8	14	10	164	0.9
Manchuria	4	1	1	3	2	2	2	1	2	1	1	20	0.1
Minsturdi (New)	9	5	5	2	1	5	4	6	2	2	4	45	0.3
Hero	0	1	0	3	2	1	1	2	0	2	8	20	0.1
Alpha	20	36	14	6	7	9	15	8	17	13	18	163	0.9
Colsess	162	170	106	117	108	118	114	135	121	110	136	1397	8.4
Black Hulless	13	6	6	9	6	4	4	6	10	6	9	79	0.5
Nepal	4	4	1	3	4	3	4	2	3	4	5	37	0.2
Minsturdi (Old)	5	3	7	5	5	5	5	8	3	7	3	56	0.3
Total per cent smut	1.3	1.3	1.0	0.9	0.9	1.0	0.9	1.0	1.0	1.0	1.1		1.0
Total number smutted heads	398	391	301	288	278	296	265	296	315	301	341		

The occurrence of loose smut was recorded in a barley-variety and seed-treatment experiment conducted at Ames in 1929. The percentages of smut are approximate because the rod rows were estimated to have 800 culms each. The smutted heads were counted in 836 rod rows and data are presented in table 3.

The data in table 3 show that 5.6 and 8.4 per cent of loose smut occurred in Glabron and Colsess, respectively, and less than 1 per cent in any of the other varieties. All the seed used in this experiment was obtained from one field the preceding year; therefore, these data may indicate the relative susceptibility of the varieties to loose smut. Seed treatment seems to have had some effect in the control of loose smut in the first eight varieties in table 3 and little, if any, effect on the other varieties. A summary of the smut counts in these eight varieties shows there were 58 smutted heads in the means of the checks and 11 on plants from seed treated with Pa10.

According to the Plant Disease Reporter 1927 (United States Department of Agriculture) scab of barley, caused by *Gibberella saubinetti* (Mont.) Sacc., is not considered an important disease outside of Iowa. In this State, however, there has been an estimated annual loss of 1.4 per cent. The average loss for the past five years (1924–1928) is 2.2 per cent. The occurrence is somewhat sporadic; serious damage occurred in 1919 (5.0 per cent loss) and 1928 (8.0 per cent loss). Recently scab has been charged with making barley unfit as a food for swine.

Covered smut (*Ustilago hordei* (Pers.) Kell. & Sw.) has caused an annual loss of 1.0 per cent in Iowa. The average loss for the past five years (1924–1928) was 1.3 per cent. In the United States as a whole, this disease is considered the most important of those occurring on barley. In Iowa, however, it would rank, at most, third and possibly fifth.

Barley diseases of minor importance occurring in Iowa are: Leaf rust, spot blotch, net blotch, ergot, anthracnose, powdery mildew, and bacterial blight. These probably cause a combined annual loss of about 2.0 per cent. In certain years or on certain varieties some of these diseases are important.

Spot blotch, caused by *Helminthosporium sativum* Pam. King & Bakke, is recorded (1909) as having caused 50.0 per cent loss in the two-rowed variety, Chevalier. Also there were severe infections in 1915 and 1917, injuring 10.0 per cent and 4.0 per cent, respectively.

Several times in the past 20 years net blotch, caused by *Pyrenophora teres* (Died.) Drechs., has injured the crop 5.0 per cent.

Severe infections of bacterial blight, caused by *Pseudomonas translucens* Jones, Johnson, and Reddy, have been observed in 1927 and 1928 on only one variety, Colsess. In 1929, Hero also was severely attacked.

Data are presented in table 4 on the occurrence of a number of diseases in varieties of barley grown at Ames and Mason City, Iowa, in 1929. The absence of a disease is designated by 0 in the table and the severity by

TABLE 4.—*Occurrence of a number of diseases in barley varieties grown at Ames and Mason City, Iowa, in 1929 (0 = absence; 1 = present but injury not apparent; 2 = present and caused considerable injury)*

Variety	Spot blotch	Net blotch	Scab	Stem rust	Leaf rust	Bacterial blight	Ligule blight unknown [a]	Powdery mildew
Velvet	0	1	0	2	0	0	0	0
Glabron	1	1	0	2	0	0	1	1
Wis. Barbless	0	1	1	1	0	0	1	0
Spartan	2	0	0	1	0	0	1	0
Bonami	0	1	0	1	0	0	0	0
Manchuria	0	1	1	1	0	0	0	0
Wis. 5–1	0	1	1	2	1	0	0	1
Featherston	0	1	1	1	0	0	1	0
OAC 21	0	1	1	1	0	0	1	0
Minsturdi	0	0	1	1	1	1	0	0
Trebi	1	2	2	1	1	1	2	0
Sandrel	2	2	2	1	0	1	2	0
Hero	2	1	0	1	0	2	2	0
Horn	2	1	0	1	0	0	1	0
Alpha	1	1	0	1	0	0	0	0
Colsess	1	1	1	2	0	2	1	2
Black Hulless	1	1	0	1	0	0	0	0
Nepal	1	1	2	1	0	0	0	0
Minsturdi (Old)	0	1	1	1	1	1	0	0

[a] Not scald, *Rhynchosporium secalis* (Oud.) Davis.

figures 1 to 3. 1 means that the disease was present but injury not noticed; 2, that real injury was caused; and 3, that the economic value of the crop was almost completely destroyed.

TABLE 5.—*Estimated percentage losses from barley diseases in Iowa*

Disease	Percentage loss			
	1906–1928	1924–1928	1928	1929
Stem rust	3.5	1.0	0.5	0.5
Stripe	2.7	3.3	4.0	5.0
Loose smut	1.6	0.7	tr.	1.5
Scab	1.4	2.2	8.0	tr.
Covered smut	1.0	1.3	1.0	tr.

Table 4 shows that no variety is immune from all the minor diseases. Colsess stands out as a susceptible variety, being injured by stem rust, bacterial blight, and powdery mildew. Besides these diseases, it had 1.8 per cent stripe (table 1) and 8.4 per cent loose smut (table 3) and was the only variety in which ergot was common.

A summary of the losses is presented in table 5.

METHODS AND MATERIALS

Preliminary field experiments on the control of barley stripe by seed treatments with dust fungicides were conducted at Ames, Iowa, in 1927. A large number of dusts were prepared and tested by planting the treated and untreated barley seed in rod rows. Data on the occurrence of stripe in these rows were obtained.

Fifteen of the 96 treatments tried in 1927 resulted in rod rows having no stripe plants and no plants infected with loose and covered smut. Each of the seventeen check rows had some plants affected with stripe and loose smut. The results of the experiment served to indicate chemical combinations which had disinfecting properties but apparently did not injure the seed. One combination, consisting of mercury chloride and the addition product of furfural and sodium bisulphite, gave especially promising results. Subsequent tests in the greenhouse indicated that furfural was not necessary in this combination. Fungicidal dusts of this type, with the furfural omitted, were made and used in the 1928 and 1929 field experiments.

In 1928 and 1929, the number of disinfectants was decreased and the number of field experiments was increased, so that yield data could be secured. Seed treatments were made at the rate of three ounces of dust fungicide per bushel of seed.

In one type of experiment, a barley variety and eight dust disinfectants were used. Single rod-rows were made the unit, and all treatments were replicated ten times in 1928 and 11 times in 1929. Experiments of this kind were located at Mason City, Iowa, and at two places near Ames, Iowa, *i.e.*, Agronomy Farm and the Plant Pathology plots.

In another type of experiment, 20 varieties of barley were treated with two of the dust fungicides and planted at Mason City, Iowa, in units of four rod-rows instead of one. This type of experiment was modified in 1929 by changing or omitting a few of the varieties, increasing the number of dust fungicides, and including three dates of planting at Ames and two dates of planting at Mason City.

In the first set of experiments, the number of stripe-infected plants was recorded, when the grain was in the milk stage. All the plants were pulled in one complete replication and the diseased plants separated from the

healthy ones. A rod-row thresher was used in separating the grain from the straw.

COMPOSITION OF THE DUST FUNGICIDES

Not all of the dust fungicides gave promising results. Therefore, it is necessary only to give the composition of Bar 1, Bar 3, Bar 4, P1C, and Bow.

Bar 1 was made as follows: To 2.7 grams $HgCl_2$ in solution enough NaOH solution was added to change mercury to the yellow oxide. The supernatant liquid was decanted and the yellow oxide triturated with 2 gm. $NaHSO_3$. After adding 22.3 gm. talc, it was mixed thoroughly, air dried, and pulverized.

Bar 2 was made by mixing equal parts of Bar 1 and talc.

Bar 3 was somewhat similar to Bar 1 except that the ingredients were mixed dry. It was expected that certain reactions would take place when the treated seed was sown in moist soil. Bar 3 was made as follows: 6 gm. $NaHCO_3$, 6 gm. $NaHSO_3$, 8 gm. $HgCl_2$, and 80 gm. talc were mixed and pulverized.

Bar 4 was made by mixing and pulverizing 3 gm. $HgCl_2$, 10 gm. $NaHSO_3$, and 87 gm. of talc.

P1C was made as follows: 10 gm. $HgCl_2$ and 5 c.c. cresol were placed in a mortar and triturated. Strong NaOH solution was added until the mass was yellow and thick. Strong copper-sulphate solution was added in excess of the reaction. Ninety grams of talc was added and the mixture dried and pulverized.

Bow contained 10 per cent hexamethylenetetramine, 30 per cent $CuSO_4 . H_2O$, 30 per cent $CaCO_3$, and 30 per cent talc.

EXPERIMENTAL STUDIES

It has been shown that the four diseases that probably tax the farmer most heavily are stripe, smut, scab, and rust. The first two are seed-borne diseases and are controlled at least partially and practically by seed treatment. The fact that scab and rust are most in evidence and produce the major part of their damage late in the growing season indicates that these losses may be much reduced by early maturity of the crop, thereby escaping much of the usual damage. However, early sowing, usually accompanied by cool soil temperatures, provides exceptionally favorable conditions for the seed-borne diseases, especially barley stripe.

The development of a dust fungicide to control stripe seemed to offer the most satisfactory immediate approach to the problem of barley-disease control. Field experiments were performed to determine the effect of dust fungicides on stripe and yields of barley.

TABLE 6.—*Data on the occurrence of barley stripe (H. gramineum), and yields of grain from a seed-treatment experiment using barley, variety Minsturdi, 1928*

Location of plots	Treatment	Number of plants counted		Per cent stripe plants	Yields bushels per acre	Increase following treatment	
		Healthy	Diseased			Bushels	Per cent
Mason City, Iowa	1 EE	376	19	4.9			
	2 EE2	394	69	14.9			
	3 Pb8	382	47	11.0			
	4 Bar 1	412	11	2.6	52.6	9.0	20.7
	5 Check	335	53	13.7			
	6 Bar 2	398	28	6.6			
	7 Bar 3	418	8	1.9	53.6	10.0	23.1
	8 P1C+	378	26	6.4			
	9 P1C	428	19	4.3	49.6	6.0	13.8
	10 Check	383	55	12.5	43.6		
Pathology plots, Ames, Iowa	1 EE	422	119	22.0	32.8	−1.2	−3.5
	2 EE2	444	99	18.4	32.3	−1.4	−4.2
	3 Pb8	464	46	9.0	36.8	3.4	10.2
	4 Bar 1	516	6	1.1	40.4	7.4	22.4
	5 Check	492	98	16.6	32.7		
	6 Bar 2	477	31	6.1	37.9	5.1	15.5
	7 Bar 3	503	7	1.4	41.1	8.1	24.5
	8 P1C+	492	36	6.8	36.8	3.6	10.8
	9 P1C	503	5	1.0	39.2	5.9	17.7
	10 Check	449	145	24.8	33.4		
Agronomy plots, Ames, Iowa	0 Check				29.6		
	1 EE	353	225	38.9	31.9	2.8	9.6
	2 EE2	348	190	35.3	30.7	2.1	7.3
	3 Pb8	311	151	32.7	34.4	6.2	22.0
	4 Bar 1	384	26	6.3	42.8	15.1	54.5
	5 Check	319	195	38.0	27.2		
	6 Bar 2	428	62	14.4	38.7	11.2	40.8
	7 Bar 3	418	17	3.9	41.2	13.3	47.7
	8 P1C+	405	47	10.4	37.8	9.5	33.6
	9 P1C	432	17	3.8	41.8	13.2	46.2
	10 Check	368	216	37.0	28.9		

Table 6 presents data on the occurrence of stripe plants in the variety Minsturdi and on the yields obtained from plots located at three places in Iowa in 1928. At each place there were 10 plots for each dust fungicide and 20 check plots sown with nontreated seed. One plot or replication was destroyed in obtaining the stripe counts, so that only nine replications were used in determining the acre yields.

With the use of seed from the same lot at all three places, about twice as many stripe plants occurred in the checks at the Agronomy Farm plots as in the checks at the Plant Pathology plots and about twice as many at the latter place as at the Mason City plots. The dates of planting at these three places were March 31, April 19, and April 26, respectively. Soil temperatures gradually rose from March 31 to April 26, and the results are in agreement with those of Ravn (5) and of Johnson (1) in that cool soil temperatures are favorable to the occurrence of barley stripe.

The date in table 6 also show that the Bar 1 and Bar 3 treatments, on the whole, gave the most effective control of stripe and the largest increases in acre yields. P1C treatment also increased yields, especially when the barley seed germinated under very cool soil conditions. Yield increases from these three best treatments ranged from 5.9 to 15.1 bushels, or 13.8 per cent to 54.5 per cent. The data show that stripe seriously affects yields and, that, in susceptible varieties planted early, the fungicidal control of

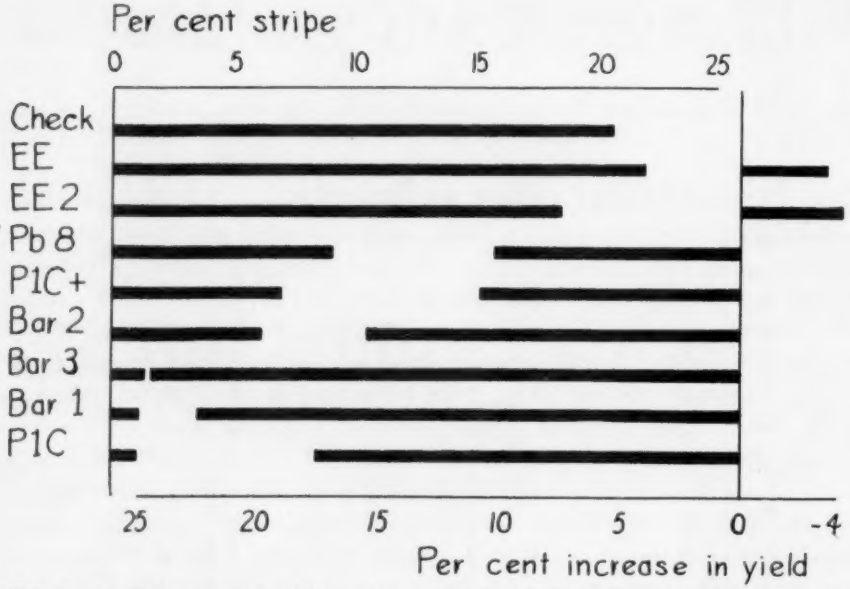

FIG. 1. Percentage stripe plants and percentage increases in yield following seed treatments of barley, Agronomy Farm, Ames, Iowa, 1928. (See Table 6.)

this disease may become one of the important practices in the successful culture of barley.

Figures 1 and 2 present graphically some of the data from the Agronomy Farm plots and the Plant Pathology plots shown in table 6. These graphs show the negative correlation between percentage of stripe plants and percentage increases in yields following seed treatments.

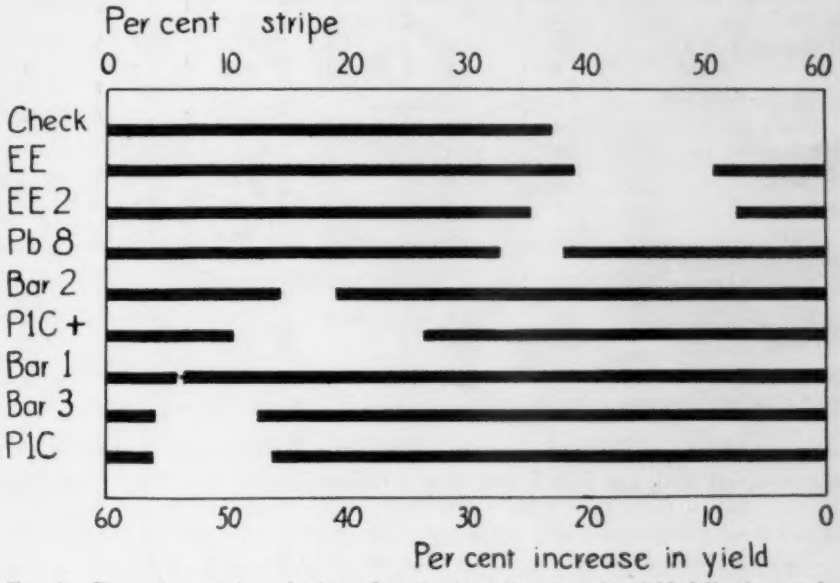

FIG. 2. Percentage stripe plants and percentage increases in yield following seed treatments of barley, Plant Pathology plots, Ames, Iowa, 1928. (See Table 6.)

Figures 1 and 2 show graphically that with each treatment used, any decrease in percentage of striped plants was followed almost invariably by a somewhat proportional increase in yield. However, when individual treatments are compared, the graphs show that Bar 1 and Bar 3 treatments were followed by larger increases than P1C treatments, although P1C treatments controlled stripe as well as or better than Bar 1 and Bar 3. It is probable that P1C was more injurious to the barley seed than Bar 1 or Bar 3.

In another experiment in 1928, using stripe-infected barley of the variety Minsturdi, 32 dust fungicides were tested in rod rows replicated five times. Yield data were obtained for 8 of these dust treatments and are shown in table 7.

In this case the results are the means of only four replications of each treatment and, therefore, are not so reliable as those shown in table 6. The

TABLE 7.—*Prevalence of barley-stripe-infected plants and the yields of grain from treated and nontreated barley seed of the variety Minsturdi grown at Ames, Iowa, 1928*

Treatments	Striped plants per rod row		Acre yields[a] in bu.		Increase	
	No.	Per cent	Treated	Checks	Bu.	Per cent
15 Check	42	8.4		36.3		
16 Corona dust 1	15	3.0	45.3	36.8	8.5	23.1
17 " " 2	8	1.6	43.0	37.3	5.7	15.3
18 16 Furfurin + 20 $CuSO_4$	14	2.8	43.2	37.8	5.4	14.3
20 Check	85	17.0		38.8		
25 Check	102	20.4		42.1		
26 Bar 4	5	1.0	49.4	41.2	8.2	19.9
28 Pb19	16	3.2	40.0	39.4	0.6	1.5
29 Hydrofuramid 28 $CuSO_4 \cdot H_2O$ 17, talc 55	14	2.8	44.4	38.3	6.1	15.9
30 Check	78	15.6		37.5		

[a] Four replications.

data are offered to show the results of the Bar 4 treatment, so that it may be compared with the Bar 1 and Bar 3 treatments in the Plant Pathology

TABLE 8.—*Prevalence of barley stripe and yields of grain from treated and nontreated seed of the variety Minsturdi, grown at Ames, Iowa, 1929*[a]

Treatment	Plants counted		Stripe plants	Increase in healthy plants following treatment	Acre yield	Increase following treatment	
	Healthy	Stripe					
	No.	No.	P. ct.	P. ct.	Bu.	Bu.	P. ct.
Barley dope 5% HgO (yellow oxide)	423	68	13.8	4.8	38.15	3.56	10.3
Sterocide	437	69	13.6	8.3	38.95	3.82	10.9
575	442	69	13.5	9.5	39.45	3.78	10.6
Check	477	32	6.3	18.2	43.35	7.14	19.7
W 1	410	136	24.9		36.75		
Bow	466	15	3.1	15.5	37.65	1.44	4.0
1234–57–2	485	49	9.2	20.2	42.50	6.83	19.2
Bar 4	436	66	13.1	8.1	40.80	5.67	16.1
Check	468	38	7.5	16.0	42.55	7.96	23.0
	397	113	22.2		34.05		

[a] Date of planting, April 13.

plots, the results of which are presented in table 6. These treatments are on the same lot of seed planted side by side in the same field on the same day. Because these data indicated that Bar 4 was equal to Bar 1 and Bar 3, both in stripe control and effect on yields, Bar 4 was used extensively in experiments conducted in 1929.

TABLE 9.—*Prevalence of barley stripe and yields of grain from treated and nontreated seed of the variety Minsturdi, planted April 22 and April 30, Ames, Iowa, 1929*

Treatment	Planted April 22				Planted April 30			
	Stripe	Acre yield	Increase		Stripe	Acre yield	Increase	
	P. ct.	Bu.	Bu.	P. ct.	P. ct.	Bu.	Bu.	P. ct.
Barley dope	16.3	——	——	——	16.4	——	——	——
5% HgO	9.0	——	——	——	8.5	——	——	——
Sterocide	8.2	——	——	——	6.4	——	——	——
575	5.2	33.35	4.50	15.6	——	40.30	9.70	31.7
Check	22.4	28.85			15.6	30.60		
WB	2.1	33.40	4.55	15.8	——	37.35	6.75	22.1
Bow	8.9	——	——	——	5.9	——	——	——
1234–57–2	11.3	——	——	——	6.1	——	——	——
Bar 4	6.3	33.05	6.85	26.1	5.8	39.00	7.60	24.2
Check	21.7	26.20			17.0	31.40		

Tables 8 and 9 present data from experiments in 1929 on the variety Minsturdi, in which Bar 4 was used as a seed treatment. The three experiments here reported consisted of 11 replications of the treatments and checks, 10 of which were harvested for yields. Yield data were not obtained on some of the treatments in two of the experiments.

The data in tables 8 and 9 show that conditions for the development of stripe were about equal for the first two dates of planting, April 13 and 22, and only slightly less favorable for the third planting on April 30. The percentage of stripe was at no time so high as it was in the first planting in 1928 (Table 6). However, the soil temperatures remained comparatively low all through April, resulting in little decrease in stripe in the successive plantings. The data also show that Bar 4 did not control stripe so effectively as was indicated by the 1928 data, but the increases in yields (23.0, 26.1, and 24.2 per cent, respectively) were large in comparison with the percentage increases in healthy plants (15.2, 15.8, and 10.5 per cent, respectively).

Table 10 presents the data from two seed-treatment experiments in which the variety Minsturdi was used. The one at Ames was planted April 30 and the one at Mason City was planted May 3. Ten replications of the checks and treatments were harvested at each place.

TABLE 10.—*Prevalence of barley stripe and the yields of grain from treated and nontreated seed of the variety Minsturdi grown at Ames and Mason City, Iowa, 1929*

Treatment	Per cent stripe		Acre yields		Bu. increase		Percentage increase	
	Ames	Mason City	Ames	Mason City	Ames	Mason City	Ames	Mason City
Check	17.9	16.3	34.6	20.3				
Ceresan	0.25	0.25	39.3	23.9	5.2	3.76	15.2	18.7
1234–57–2	0.75	5.0	36.2	23.5	2.6	3.52	7.7	17.6
5% HgO	3.9	9.0	38.8	21.4	5.7	1.58	17.4	8.0
Sterocide	10.1	16.5	36.5	22.2	4.0	2.54	12.2	12.9
Check	15.3	12.8	32.0	19.5				
W 1	3.7	6.8	32.2	22.6	0.3	2.94	−0.9	15.0
Bar 4	6.2	6.0	40.1	23.5	7.0	3.68	21.2	18.6
Barley dope	15.5	12.8	37.2	23.0	3.6	3.02	10.7	15.1
Bow	3.5	9.3	34.7	21.9	0.6	1.76	2.0	8.7

The data in table 10 show that Ceresan effectively (98.5 and 98.3 per cent) controlled stripe and increased yields 15.2 and 18.7 per cent, respectively. Although Bar 4 was only 63 and 59 per cent effective in controlling stripe, the yields were increased 21.2 and 18.6 per cent, respectively.

The effect of dust fungicides on the varieties Trebi and Colsess

Table 11 presents the results of a seed-treatment experiment in 1928 on barley, variety Trebi, involving the same series of dust fungicides as we used on the variety Minsturdi. It is interesting to note that in this variety

TABLE 11.—*Acre yields from treated and nontreated barley seed, variety Trebi, grown at the Agronomy Farm in ten rod-row replications, Ames, Iowa, 1928*

Treatment	Acre yields in bushels		Increase	
	Treated	Check	Bu.	Per cent
0 Check		45.50		
1 EE	45.60	45.75	−0.15	−0.3
2 EE2	46.55	46.01	0.54	1.2
3 Pb8	48.80	46.27	2.53	5.5
4 Bar 1	48.62	46.52	2.10	4.5
5 Check		46.77		
6 Bar 2	47.50	47.06	0.44	0.9
7 Bar 3	48.35	47.36	0.99	2.1
8 P1C+	48.17	47.66	0.51	1.1
9 P1C	50.25	47.96	2.29	4.8
10 Check		48.25		

the seed did not carry stripe and, therefore, no stripe plants developed in the plot.

Table 11 shows that, although there was no stripe disease to control, the yields were not decreased by any of the treatments except EE, and this decrease was not significant. This suggests that none of the dust fungicides in the concentrations used was injurious to this variety of barley.

The yield data in table 12 were recorded from an experiment located at Mason City, Iowa, in which the same lot of barley seed was used as in table 11.

TABLE 12.—*Acre yields from treated and nontreated barley seed, variety Trebi, grown at Mason City, Iowa, in five rod-row replications, 1928*

Treatment	Acre yields	Increase	
	Bushels	Bu.	Per cent
Check	70.0		
Bar 1	69.4	−0.25	−0.36
Bar 3	78.9	9.75	14.1
P1C	63.9	−5.25	−7.6
Check	68.3		

The results presented in table 12 are not so uniform as those in table 11, probably because only five replications were harvested. However, the results are in agreement with those of other experiments in that Bar 1 and Bar 3 are more satisfactory than P1C and suggest further that P1C may be injurious to the seed.

TABLE 13.—*Prevalence of loose smut and yields of grain from treated and nontreated seed of the variety Colsess, Ames, Iowa, 1929*

Treatment	Loose smut	Acre yield[b]	Increase	
	P. ct.	Bu.	Bu.	P. ct.
1 Barley dope	5.9	41.00	2.70	7.1
2 5% HgO (yellow oxide)	6.0	38.50	0.20	0.5
3 Sterocide	5.8	43.70	5.40	14.1
4 575	5.7	43.40	5.10	13.3
5 Check[a]	5.8	38.30		
6 WB	6.2	42.00	3.70	9.7
7 Bow	5.8	39.70	1.40	3.7
8 1234–57–2	5.6	41.60	3.30	8.6
9 Bar 4	5.6	39.20	0.90	2.3
10 Check	6.4	38.30		

[a] Checks had nearly two per cent stripe.

[b] Five replications.

Table 13 presents the results of a seed-treatment experiment in 1929 on barley, variety Colsess. This variety, as shown in table 4, is susceptible to many barley diseases but not especially susceptible to stripe (1.8% in 1929).

The data in table 13 show that none of the treatments was effective in controlling loose smut but that several treatments were followed by increased yields.

RESULTS OBTAINED FROM DUST FUNGICIDES ON MANY VARIETIES OF BARLEY

Table 14 gives the results of two dust fungicides on 20 different varieties of barley grown at Mason City, Iowa, in 1928. The seed of each variety was planted in four rod-rows and there were no replications.

Table 14 shows that the mean yield of 20 varieties was slightly higher when the barley seed was treated with Bar 1 than when not treated, but the

TABLE 14.—*Yields and differences in yields due to seed treatment of barley varieties at Mason City, Iowa, 1928*

Variety	Control	Bar 1		EE	
	Yield	Yield	Difference	Yield	Difference
OAC 21	52.3	54.6	+ 2.3	53.2	+ 0.9
Minsturdi	50.2	53.8	+ 3.6	47.5	- 2.7
Trebi	62.3	75.5	+13.2	73.2	+10.9
Velvet	78.0	79.2	+ 1.2	67.5	-10.5
Comfort	70.5	75.2	+ 4.7	68.2	- 2.3
Glabron	65.5	55.2	-10.3	62.5	- 3.0
Wis. Barbless	63.7	57.5	- 6.2	58.7	- 5.0
Manchuria	56.2	51.0	- 5.2	48.5	- 7.7
Wis. No. 5–1	50.0	55.5	+ 5.5	54.5	+ 4.5
Featherston	53.5	47.7	- 5.8	61.5	+ 8.0
Alpha	59.2	56.2	- 3.0	60.5	+ 1.3
Sandrel	69.2	58.7	-10.5	70.0	+ 0.8
Hero	50.7	62.5	+11.8	54.2	+ 3.5
Horn	52.2	53.7	+ 1.5	61.7	+ 9.5
Blk. Hulless	44.5	45.0	+ 0.5	50.0	+ 5.5
Nepal	33.0	32.5	- 0.5	37.5	+ 4.5
Colsess	49.0	49.5	+ 0.5	55.0	+ 6.0
Bonami	52.5	52.2	- 0.3	50.7	- 1.8
Ia. No. 99	46.2	54.2	+ 8.0	51.5	+ 5.3
Swiss	43.5	45.5	+ 2.0	42.0	+ 1.5
Average	55.1	55.8	+ 0.7	56.4	+ 1.3
Odds			2.15:1		5.54:1

TABLE 15.—*Summary of acre yields of 18 varieties of barley in a seed-treatment and time-of-planting experiment, ten replications in all, conducted at Ames and Mason City, Iowa, in 1929*

Variety	Acre yield bushels					Increase			
	No tr.	Ceresan	Bar 3	Bow	No tr.	Ceresan	Bar 3	Bow	Mean
						Bu.	Bu.	Bu.	Bu.
Minsturdi (Old)	28.70	34.05	34.40	29.80	28.65	5.37	5.72	1.12	4.07
Minsturdi (New)	35.20	41.60	36.05	35.65	32.55	7.72	2.17	1.77	3.89
Wis. 5–1	29.70	32.95	31.10	31.75	30.10	3.05	1.20	1.85	2.03
Bonami	29.40	30.50	33.45	30.30	30.00	0.80	3.75	0.60	1.72
Glabron	34.10	36.90	37.90	33.95	35.40	2.15	3.15	−0.80	1.50
Velvet	32.80	32.60	35.50	33.15	31.85	0.23	3.17	0.82	1.41
Horn	38.85	40.25	40.75	38.75	38.20	1.72	2.22	0.22	1.39
Nepal	23.50	24.30	23.95	24.80	22.80	1.15	0.80	1.65	1.20
Black Hulless	24.55	28.30	24.75	28.45	27.40	2.32	−1.23	2.47	1.19
Colsess	34.85	34.85	36.05	35.30	33.75	0.55	1.75	1.00	1.10
Featherston	28.00	29.15	30.10	28.60	28.75	0.77	1.72	0.22	0.90
Wis. Barbless	34.75	37.30	36.00	37.65	38.75	0.55	−0.75	0.90	0.23
Manchuria	28.25	32.15	28.35	30.20	32.35	1.85	−1.95	−0.10	−0.07
Alpha	42.90	33.40	42.20	36.30	32.55	−4.33	4.47	−1.43	−0.43
OAC 21	30.60	31.45	26.55	31.45	30.20	1.05	−3.85	1.05	−0.58
Spartan	31.00	30.10	30.35	28.75	30.50	−0.65	−0.40	−2.00	−1.02
Sandrel	42.45	41.70	38.90	42.45	42.45	−0.75	−3.55	0.00	−1.43
Hero	36.15	32.00	36.40	35.65	36.85	−4.50	−0.10	−0.85	−1.82
Trebi	48.50	47.30	44.10	45.10	47.35	−0.63	−3.83	−2.83	−2.43
Av. acre yield—Bu.	33.38	34.26	34.10	33.58	33.18				
Increase—Bu.		0.98	0.82	0.30					
Increase—P. ct.		2.9	2.5	0.9					

results are not significant in terms of odds. The small increases in yields from seed treatment may be due to the fact that the seed used was almost entirely free from stripe and that only a few varieties had an appreciable amount of covered smut. The arrangement of the plot may not have been satisfactory from the standpoint of sampling the soil, because the nontreated rod rows were in one nonreplicated block. A similar block of treated rod rows was on each side of the nontreated block.

In 1929, 18 barley varieties were planted twice at early, medium, and late dates at Ames and at early and late dates at Mason City, Iowa. A variety was represented in each of the ten plantings by four rod rows from nontreated seed and seven rod rows each of which was from seed treated with a different dust fungicide. Yield data were obtained from only three of the seed treatments at Mason City. A summary of the results at both places is presented in table 15.

The data in table 15 show that, of the three treatments on which yield data were obtained, Ceresan gave the highest average increases.

Yield data were obtained at Ames on the effects of all the dust fungicides used. Here the acre yields were computed on 6 replications of each treatment and 12 replications of the checks. The plant development at Ames was more uniform than at Mason City. At the latter place, the early planting was under excessive moisture conditions and the late planting met with such severe drought as to seriously decrease the yields. It seems probable that the results of the portion of the experiment located at Ames are more significant than the results of the whole experiment. The yield data from the plots located at Ames are presented in table 16.

Table 16 shows that Trebi was the highest yielding variety and that, of the seven dust fungicides used, Bar 4 gave the highest increase when the yields of all the varieties were averaged.

Table 17 presents the acre yields of the varieties when grown at Mason City, Iowa.

The data in table 17 show that Trebi was again the highest yielding variety. A few varieties responded differently at Mason City. The variety Colsess is probably outstanding in this respect, yielding fourth from the lowest at Ames and third from the highest at Mason City.

The occurrence of stripe in plants from nontreated and treated seed of the different varieties is recorded in table 18. Stripe in the different varieties is compared with the stripe in Minsturdi, the most susceptible variety.

The data in table 18 show that Ceresan controlled stripe most effectively, followed in order by Bar 3 and Bar 4. The fungicidal dust containing 10 per cent paraformaldehyde was the most injurious to barley seed, reducing

TABLE 16.—*Mean acre yields from barley seed of 18 varieties treated and not treated and planted twice at three dates in 1929, Ames, Iowa*

Variety	Check	Ethyl iodide	Ceresan	Bar 3	Bar 4	Pa 10	Bow	$NaHSO_3$	Check	Mean acre yields of checks and treatments	Per cent yield in comparison with Trebi
Trebi	49.67	52.83	49.33	48.67	45.92	44.33	47.00	50.25	48.42	48.49	100
Sandrel	44.25	45.42	42.58	41.42	38.42	40.67	44.08	44.75	42.50	42.68	88
Horn	41.75	44.42	44.00	43.92	42.17	39.58	38.42	41.58	38.67	41.61	86
Alpha	50.67	44.92	33.67	44.00	45.25	44.42	36.58	31.67	32.67	40.43	83
Glabron	35.92	37.25	41.00	43.08	37.75	34.08	38.00	38.42	39.67	38.35	79
Hero	38.75	35.75	34.50	38.25	37.75	38.33	40.67	37.67	41.92	38.18	79
Velvet	36.50	36.42	36.00	39.67	41.83	35.67	36.08	38.67	34.42	37.25	77
Minsturdi (New)	38.67	34.17	41.83	38.58	35.83	30.50	36.58	33.67	35.25	36.12	75
Wis. Barbless	37.58	34.25	35.83	34.00	35.92	37.75	37.50	40.08	36.50	36.60	75
Wis. 5–1	35.33	34.58	40.08	34.67	38.17	32.83	36.58	34.25	36.08	35.84	74
Spartan[a]	32.88	36.13	33.00	34.25	33.13	36.88	32.00	29.88	33.38	33.50	69
Manchuria	30.83	33.50	34.67	32.50	37.92	30.17	33.17	35.33	33.67	33.53	69
OAC 21	33.75	32.92	35.67	31.50	36.58	33.83	33.00	33.67	31.75	33.63	69
Minsturdi (Old)	29.17	30.58	36.33	38.67	35.75	31.92	34.92	32.08	31.92	33.48	69
Bonami	31.00	31.25	31.42	37.17	39.92	31.83	32.17	31.92	29.17	32.87	68
Colsess	33.58	33.92	31.50	35.75	32.83	31.17	31.25	30.42	33.58	32.67	67
Featherston	30.42	31.50	34.17	30.33	34.92	30.50	32.33	33.92	31.92	32.22	66
Black Hulless	23.67	27.33	28.83	26.42	27.58	22.17	29.17	28.17	28.42	26.86	55
Nepal	23.58	25.67	24.00	24.25	23.00	20.75	25.00	21.42	23.17	23.43	48
Acre yields	35.68	35.94	36.23	36.69	36.88	34.07	35.50	35.15	34.90		
Increase—Bu.		0.34	0.73	1.29	1.58	−1.13	0.40	0.15			
Increase—P. ct.		0.95	2.06	3.64	4.48	−3.21	1.14	0.43			

[a] Only 4 replications.

TABLE 17.—*Acre yields of varieties of barley from seed treated and not treated and the mean yields from both kinds of seed compared with Trebi*

Variety	Check	Ceresan	Bar 3	Bow	Check	Mean acre yield	Per cent yield in comparison with Trebi
Trebi	53.00	44.25	37.25	42.25	45.75	44.50	100
Sandrel	39.75	40.38	35.13	40.00	42.38	39.23	89
Wis. Barbless	30.50	39.50	39.00	37.88	42.13	37.80	85
Colsess	36.75	39.88	36.50	41.38	34.00	37.70	85
Horn	34.50	34.63	36.00	39.25	37.50	36.38	82
Alpha	31.25	33.00	39.50	35.88	32.38	34.40	77
Minsturdi (New)	30.00	41.25	32.25	34.25	28.50	33.25	75
Hero	32.25	28.25	33.63	28.13	29.25	30.30	69
Glabron	31.38	30.75	30.13	27.88	29.00	29.83	67
Bonami	27.00	29.13	27.88	27.50	31.25	28.55	64
Velvet	27.25	27.50	29.25	28.75	28.00	28.15	63
Minsturdi (Old)	28.00	30.63	28.00	22.13	23.75	26.50	60
Manchuria	24.38	28.38	22.13	25.75	30.38	26.20	59
Black Hulless	25.88	27.50	22.25	27.38	25.88	25.78	58
OAC 21	25.88	25.13	19.13	29.13	27.88	25.43	57
Featherston	24.38	21.63	29.75	23.00	24.00	24.65	55
Spartan	27.25	24.25	22.50	22.25	24.75	24.20	54
Nepal	23.38	24.75	23.50	24.50	22.25	23.68	53
Wis. 5–1	21.25	22.25	25.75	24.50	21.13	22.98	52
Mean	30.21	31.21	29.98	30.62	30.53	30.50	

TABLE 18.—*Prevalence of barley stripe in 18 varieties and the effect of seed treatment on strip and acre yields (yield data from Table 16), Ames, Iowa, 1929*

Number stripe plants

Varieties	No treatment	No treatment	Ethyl iodide 5%	Ceresan	Bar 3	Bar 4	Paraform 10%	Bow	$NaHSO_3$ 15%	No treatment	No treatment	Total number	Per cent stripe in comparison with Minsturdi
Velvet	3	1	6	0	0	2	4	4	5	6	5	36	12
Glabron	8	5	6	1	3	6	13	4	6	6	3	61	20
Wis. Barbless	4	1	2	0	0	0	4	3	2	3	7	26	8
Iowa 99	5	2	3	0	2	1	6	5	5	6	5	40	13
Bonami	5	6	6	0	3	1	8	3	9	7	7	55	18
Manchuria	13	7	8	0	4	3	12	4	10	11	7	79	26
Wis. 5–1	28	36	28	0	6	16	23	22	29	31	33	252	82
Featherston	12	10	6	1	1	5	3	4	6	9	9	66	21
OAC 21	8	6	5	0	1	3	2	5	6	4	2	42	14
Minsturdi	33	33	39	1	14	19	36	31	43	25	32	306	100
Trebi	1	0	0	0	0	0	0	0	0	0	0	1	tr.
Sandrel	3	3	0	0	1	4	2	1	1	1	2	18	6
Hero	1	3	0	0	0	2	1	0	0	0	1	8	3
Horn	0	0	3	0	0	0	0	2	3	2	2	12	4
Alpha	11	13	20	0	3	8	9	7	14	11	16	112	37
Colsess	10	7	6	0	1	1	7	5	11	6	6	60	19
Black Hulless	0	1	0	0	0	0	0	0	0	0	0	1	tr.
Nepal	0	0	0	0	0	0	0	0	0	0	0	0	0
Minsturdi (old)	37	58	48	0	7	25	36	18	37	40	39	345	113
Number stripe plants	182	192	186	3	46	96	166	118	187	168	176		
Per cent stripe	2.40	2.53	2.45	0.04	0.61	1.26	2.18	1.55	2.46	2.21	2.32		
Difference in p. ct. stripe in checks and treatments			−0.08	2.33	1.76	1.11	0.19	0.82	−0.09				
Acre yield increase, p. ct.			0.95	2.06	3.65	4.48	−3.21	1.14	0.43				

the yields 3.21 per cent. It is interesting to note that, of the three treatments giving an appreciable measure of stripe control (Ceresan, Bar 3, and Bar 4), the one most effective in controlling stripe was followed by the smallest increases in yields and the one least effective was followed by the greatest increases in yields. The data also indicate that Trebi, Black Hulless, and Nepal are relatively resistant to stripe.

A summary of the effect on yields of barley varieties by seed treatment with Ceresan, Bar 3, and Bar 4, is presented in table 19. The varieties on which all three treatments increased the yields are placed in the first group in the table. The second group contains the varieties of which yields were increased by two of the three treatments, and the yields of the varieties in the third group were increased by one or none of the three treatments.

Table 19 shows that, in the first group of varieties, the highest mean increase (20.8 per cent) from seed treated with Ceresan, Bar 3, and Bar 4, respectively, was on the variety Minsturdi (old seed) and ranged down to

TABLE 19.—*Effect of seed treatment with Ceresan, Bar 3, and Bar 4 on yields of 18 varieties of barley, Ames, Iowa, 1929 (data from table 16)*

Variety	Stripe	Acre yields from seeds non-treated	Increase or decrease per acre from seed treated with			Mean increase or decrease	
			Ceresan	Bar 3	Bar 4		
	P. ct.	Bu.	Bu.	Bu.	Bu.	Bu.	P. ct.
Minsturdi (Old)	10.9	30.55	+5.78	+8.12	+5.20	+6.37	20.8
Bonami	1.6	30.09	+1.33	+7.08	+9.83	+6.08	20.2
Velvet	0.9	35.46	+0.54	+4.23	+6.37	+3.71	10.5
Horn	0.3	40.21	+3.79	+3.71	+1.96	+3.15	7.8
Manchuria	2.4	32.25	+2.42	+0.25	+5.67	+2.78	8.6
Black Hulless	0.1	26.05	+2.78	+0.37	+1.53	+1.56	6.0
Mean			+2.77	+3.96	+5.09		
Glabron	1.4	37.80	+3.20	+5.28	−0.05	+2.81	7.4
Wis. 5–1	8.0	35.71	+4.37	−1.04	+3.46	+2.26	6.3
Featherston	2.5	31.17	+3.00	−0.84	+3.75	+1.97	6.3
OAC 21	1.3	32.75	+2.92	−1.25	+3.83	+1.83	5.6
Minsturdi (New)	7.7	36.96	+4.87	+1.62	−1.13	+1.79	4.8
Nepal	0.0	23.38	+0.62	+0.87	−0.38	+0.37	1.6
Spartan	0.0	33.13	−0.13	+1.12	0.00	+0.33	1.0
Alpha	3.2	41.67	−8.00	+2.33	+3.58	−0.70	−1.7
Mean			+1.36	+1.63	+1.33		
Colsess	1.8	33.58	−2.08	+2.17	−0.75	−0.22	−0.7
Trebi	0.1	49.05	+0.28	−0.38	−3.13	−1.08	−2.2
Wis. Barbless	0.9	37.04	−1.21	−3.04	−1.12	−1.79	−5.1
Sandrel	0.6	43.38	−0.80	−1.96	−4.96	−2.57	−5.9
Hero	0.3	40.34	−5.84	−2.09	−2.59	−3.51	−8.7
Mean			−1.93	−1.06	−2.51		

6 per cent on the variety Black Hulless. The mean yields of the varieties in the second group were increased with the one exception that the mean yield of Alpha was decreased 1.7 per cent. In general, the percentage increases ranged lower than in the first group (6.3 to 1.0). The average effect of these three treatments on each of the five varieties in the third group was to decrease the yield. The percentage decreases ranged from 8.7 to 0.7. The grouping in this table tends to show that some varieties of barley benefit more than others from the same seed treatments and that some varieties may be injured by seed treatments which are beneficial to many other varieties. By using other seed-treatment materials, these same varieties might react very differently and not fall in the same groups as in table 19. In table 19, the variety Colsess is in the third group, showing that it was not benefited by Bar 4. In table 13, the data show again that there was little benefit to the variety Colsess from the Bar 4 treatment, but, in the same experiment, Sterocide materially benefited this variety.

SUMMARY

There are five important diseases of barley in Iowa, namely, (1) stem rust, (2) stripe, (3) loose smut, (4) scab, and (5) covered smut.

A satisfactory seed-treatment dust fungicide should (1) control stripe and covered smut, (2) partially control loose smut and scab, and (3) decrease the prevalence of stem rust and scab by permitting earlier planting.

In 1928, certain trial dust fungicides increased the yields from stripe-infected seed 5.9 to 15.1 bushels, or 13.8 to 54.5 per cent. Stripe was more prevalent and, therefore, yield increases were greater in the early plantings.

In 1929, in five experiments in which the plots were replicated ten times, 26.1, 24.2, 23.0, 21.2, and 18.6 per cent increase in yields was obtained by seed treatment with Bar 4 on the same lot of stripe-infected seed as was used in 1928. In two similar experiments, seed treatment with Ceresan increased the yields 15.2 and 18.7 per cent, respectively.

Data on the occurrence of stripe in 18 barley varieties from seed grown in a single field the preceding year indicate that Minsturdi and Oderbrucker (Wis. 5–1) are very susceptible and that Trebi, Spartan, Nepal, and Black Hulless are resistant varieties.

In 1929, Trebi yielded highest at both Ames and Mason City, Iowa.

Data are offered which tend to show that certain varieties may be injured by seed treatment with Ceresan, Bar 3, and Bar 4 dust fungicides.

Of the dust fungicides used in these experiments, Ceresan most effectively controlled stripe and can probably be used with safety on nearly all of the common varieties.

The results with trial dust fungicides indicate that little difficulty should be experienced in developing new ones that would result in greater increases in yields from diseased seed than are now obtained.

IOWA AGRICULTURAL EXPERIMENT STATION,
AMES, IOWA.

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THE FUNGICIDAL ACTION OF SULPHUR: I. THE ALLEGED RÔLE OF PENTATHIONIC ACID[1, 2]

FRANK WILCOXON AND S. E. A. MCCALLAN[3]

INTRODUCTION

Although sulphur and certain of its compounds have been used for many years as a means of combating fungous diseases of plants, it is remarkable that there exists today no uniformity of opinion as to how its fungicidal action is exerted; and there is scarcely a compound of sulphur which might conceivably be formed from the element, under the conditions of use, to which its toxic action has not been attributed. Among these compounds are sulphur dioxide, hydrogen sulphide, sulphuric acid, thiosulphuric acid, and pentathionic acid. Some investigators maintain that the element itself is the active agent, either in finely divided form or as vapor, although its insolubility and low vapor pressure have led the majority to consider it as a source of some more toxic principle. Extensive reviews of the earlier work on this topic are given by Windisch (54), Barker, Gimingham and Wiltshire (2), Doran (12), Young (55), Vogt (48), Thatcher and Streeter (46), Goodwin and Martin (20, 21), and others. There is a great diversity of opinion expressed, and much of the early work is inconclusive and not supported by adequate experimental evidence.

The present paper presents the results of an experimental test of the hypothesis of Young (55), first set forth in 1922, that traces of pentathionic acid associated with sulphur and formed from it constitute the active fungicidal agent. It is hoped to follow this with a second communication dealing with hydrogen sulphide, which has recently become once more of interest through the work of Marsh (30).

It has been shown by Freundlich and Scholz (19), that certain types of colloidal sulphur are stabilized by adsorbed traces of pentathionic acid. These types, called hydrophilic because of the greater degree of hydration of the particles, were found by Young (55, p. 413) to be more toxic than the hydrophobic types which do not contain pentathionic acid. Later he and Williams (51, 52, 56, 57) were able to correlate the toxicity of sulphur dusts with the presence or absence of pentathionic acid on the sulphur par-

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ticles. Several of the published statements of Young in regard to the chemistry of pentathionic acid are at variance with previous chemical knowledge. For example, Young (55, p. 426) states that pentathionic acid is stable only within a narrow range of pH 4.2–5.4; whereas, it is well known that the acid is detroyed by alkalies, and rendered more stable by acids, and does not exhibit any such zone of optimum stability. Thus Freundlich and Scholz (19, p. 265), in discussing the stability of colloidal sulphur, say: "Säuren flocken deswegen so schwach, weil sie die Beständigkeit der Pentathionsäure erhöhen." Again, Young in summarizing the results of his first paper (55, p. 432) states that pentathionic acid is volatile. This is contrary to the impression of previous workers in the field of the polythionic acids, and has not been shown, so far as the present authors are aware. Young does not describe in detail his method of preparing solutions of pentathionic acid, although he and Williams (52, 57) and Williams, Liming and Young (53) give the results of spore germination tests with such solutions, and it is not clear that they ever studied pure solutions of this acid, uncontaminated by other substances. The importance of doing this will be realized when it is remembered that pentathionic acid readily reacts with many other substances forming finely divided sulphur as a product, which would complicate the interpretation of the results. The conclusions of Young have been criticized by Barker (39, p. 313; 1, p. 80) on the ground that sulphur exhibits toxicity outside the limits of pH specified by Young for the existence of pentathionic acid. Goodwin and Martin (20, p. 626) have also questioned the statements of Young regarding the volatility of pentathionic acid. Roach and Glynne (38), in their studies on the winter sporangia of *Synchytrium endobioticum* (Schilb.) Perc., were unable to find any difference in toxicity between pentathionic and sulphuric acids, at the same hydrogen-ion concentration.

In making comparisons of the toxicity of chemical substances to fungus spores, there are two requisites for obtaining accurate results which, though quite obvious, have not always received the consideration they deserve. (a) The substances whose toxicity is to be measured must be available in a pure state and of known concentration, and (b) the technique employed must be capable of distinguishing between the toxicity of the substances it is desired to compare.

EXPERIMENTAL METHODS

In these studies spore-germination tests have been employed to determine toxicity and the methods followed are those described in detail by McCallan (31, 32). These are moist-chamber tests and consist essentially of germinating the spores on glass slides in inverted moist chambers. The spores are suspended in the liquid toxic agent and pipetted as drops onto the

slides. In the case of toxic dusts, the slides are first dusted and then an aqueous suspension of spores pipetted onto the slides. The slides are supported on glass racks in the moist chamber, there being four slides to each chamber. Four drops are placed on each slide, hence there are a total of sixteen drops in each chamber. For an illustration of a moist chamber completely set up see McCallan (31). The chambers are sealed with water to preserve an atmosphere of high humidity. These chambers are placed at the desired temperature and the spores examined for germination after a given time. The percentage of germination and average length of germ tubes are recorded.

Redistilled water has been used as the medium for all tests and the temperature in all cases was within the range 19–23° C. The concentration of spores in the drops ranged from about 10 to 40 per low-power field of 1920 μ diameter. In determining the toxicity of a given compound to a given fungus, the number of spores per field was always approximately the same. The time allowed for germination before examination was from 18 to 48 hours. Since, in none of the fungus spores employed has the percentage of germination appreciably increased after 12 hours, the longer periods of time have merely facilitated greater growth of the germ tubes already formed. In most cases there was but little further elongation after 24 hours.

Four common and representative pathogenic fungi were selected for this study: *Sclerotinia americana* (Wormald) Norton and Ezekiel (13), *Botrytis* sp., of *cinerea* type, *Macrosporium sarcinaeforme* Cav., and *Uromyces caryophyllinus* (Schrank) Winter. The first three species were among those studied by Young in his first paper (55), provided that his Sclerotinia was also the common American brown-rot fungus. Young employed Sclerotinia almost exclusively in his latter studies. The *Sclerotinia americana* was isolated from infected white sweet cherries at Mattituck, New York, June, 1929. This fungus has been grown on potato-dextrose agar, where it sporulated abundantly. The spore-germination factors for *S. americana* have been discussed by McCallan (32). Since age is important, only conidia from cultures 5 to 10 days old have been used. The optimum germination temperature for these conidia is 23° C. The *Botrytis* sp., was obtained from H. H. Whetzel, Cornell University, who considers it of the *cinerea* type and designates it No. 885 in his collection. The fungus was isolated in 1927 at St. Catherines, Ontario, Canada, from marigold, and has also been grown on potato-dextrose agar, where it sporulates fairly well. The optimum germination temperature was found to be 20°–25° C. The *Macrosporium sarcinaeforme* was isolated by J. G. Horsfall at the Cornell University Experiment Station from red clover in July, 1927. This fungus was likewise grown on potato-dextrose agar and, having a wide temperature

range, the conidia germinated readily at the temperatures employed. The *Uromyces caryophyllinus* was obtained from naturally infected carnation plants of the Early Dawn variety grown in the greenhouses at this Institute. The Uromyces uredospores, as is typical of many rust fungi, do not germinate well in the centre of the drop, therefore, germination counts were confined to those in the peripheral zone of the drop. Doran's (11) narrow optimum temperature of 14° C., for the germination of these spores was not substantiated, for it was found that they germinated equally well over the range 10°, 15°, and 20° C., the latter of which was employed in these studies.

The spores from these four fungi are especially suitable because of the representative range of sulphur sensitivity each exhibits. Table 1, compiled from a number of experiments, demonstrates this varying degree of sensitivity to 300-mesh dusting sulphur.

TABLE 1.—*The degree of sensitivity to 300-mesh dusting sulphur exhibited by the spores of the fungi employed*

Fungus	Spore form	Percentage of germination		Length of germ tubes (μ)	
		Control	Sulphur	Control	Sulphur
Botrytis sp. (*cinerea type*)	conidia	99.0	99.0	200	200
Macrosporium sarcinaeforme	conidia	99.0	99.0	400	200
Sclerotinia americana	conidia	98.1	60.2	400	80
Uromyces caryophyllinus	uredospores	84.2	11.3	400	40

Under field conditions conidia of *Sclerotinia americana* are considered very sulphur-sensitive. It is therefore probable that only those spores whose germ tubes approach the vigor and length of the control would be capable of causing infection.

Much of the published work on spore-germination toxicity tests must be discredited for two reasons: first, because of the lack of sufficiently controlled factors, and secondly, because of the lack of sufficient replications and number of spores counted. In another paper (31) the importance of controlled factors has been stressed. A thorough knowledge of the conditions affecting the germination of the fungus spores to be employed is the first prerequisite. The controls must give consistent germination if any reliance is to be placed on the results obtained. In the studies with Botrytis and Macrosporium a control germination between 97.5 and 100 per cent was always obtained. In the case of *Sclerotinia americana* seventy-five per cent

of all controls gave a germination between 96.5 and 100 per cent. When the germination percentage in the controls is unusually low a disproportionate effect is obtained with the treated spores, the percentage of germination in the latter being greatly reduced. For this reason, all experiments with *Sclerotinia americana* have been discarded in which the controls have given less than 96 per cent germination. The uredospores of the obligate parasite *Uromyces caryophyllinus* are more variable in their germination.

All experiments have been performed using duplicate and, in some cases, triplicate and quadruplicate moist-chamber tests. In general, but one microscopic field has been counted in each spore-suspension drop; however, in the case of low spore-suspension concentrations more fields have been counted. From 600 to 2000 spores have been counted from the eight slides constituting a duplicate moist-chamber experiment. The larger the number of spores counted the smaller can be the significant difference between treatments. In any experiment of this kind, it is necessary to balance the time and labor involved in counting a large number of spores against the precision attainable in the final result and effect a compromise which will give the desired precision.

From the data obtained in 250 representative duplicate tests, the standard deviation of a single moist-chamber test was calculated by the method of Fleisch (14), and that of the difference between two such tests by the usual formula $\sigma^2_{A-B}=\sigma^2_A+\sigma^2$. The significance of any observed difference between two treatments may then be estimated by referring to a table of values of the probability integral. Unless the difference is at least twice its standard deviation it can not be considered very significant. These values, calculated for five different germination-percentage classes, are shown in table 2.

TABLE 2.—*The average percentage of deviation of representative duplicate tests from their mean, and the difference in germination percentage required to show a significant difference between treatments, calculated for five germination-percentage classes*

Germination—percentage class	Total number duplicate tests	Average percentage of deviation of duplicates from their mean	Standard deviation of single test: per cent	Standard deviation of difference between two similar tests: per cent	Germination—percentage difference to give odds of 50–1
0– 20	50	0.99	2.27	3.21	7.45
20– 40	50	2.60	4.80	6.79	15.75
40– 60	50	3.78	7.46	10.55	24.48
60– 80	50	2.76	5.61	7.93	18.50
80–100	50	0.45	1.19	1.68	3.90

It will be observed that the mean deviation of duplicates is least in the 0–20 and 80–100 per cent groups, and greatest in the 40–60 per cent group. Because of the variation in the viability of the spores, a repetition of tests at different times, that is different experiments, will not give such consistent results as duplicates of the same experiment at the same time. A similar effect has been observed by Smith (42, p. 31).

THE TOXICITY OF PENTATHIONIC ACID

The chemistry of pentathionic acid

Historical.—Pentathionic acid, $H_2S_5O_6$, has been the subject of numerous investigations (17, 18, 28, 29, 41) since its discovery by Wackenroder (49) more than eighty years ago, in the solution obtained by passing hydrogen sulphide and sulphur dioxide into water. The difficulties encountered in preparing the salts of this acid in pure form suitable for analysis led some workers to doubt its existence. Spring (44, 45) in a series of papers, the last of which was published in 1882, presented a critical discussion of previous work and concluded that the alleged pentathionic acid was a solution of sulphur in tetrathionic acid. In 1888 Debus (10) published the results of a very thorough study of the Wackenroder solution in the course of which methods were devised for obtaining several of the salts in pure form, by treatment of the concentrated solution with the acetate of the metal whose salt was desired. It was also shown that the salts could be recrystallized from an acidulated solution with less decomposition than from pure water. The work of Debus eliminated all doubt as to the existence of the acid, and subsequent investigators have dealt with the mode of its formation and decomposition (16, 24, 35, 36), structure, physical properties (15, 23), and its quantitative determination in the presence of other sulphur acids (25, 27, 37). Some of these questions have not yet been satisfactorily settled (3). It was found by Salzer (40) that pentathionic acid was formed in an acidified solution of sodium thiosulphate if a small amount of arsenious acid were present. This method of preparation of the acid and its salts has been used by Raschig (34) and has been thoroughly studied by Kurtenacker and Czernotzky (26). It furnishes a much more convenient method of preparation than the original method of Wackenroder, since, by suitable adjustment of the concentrations of the reactants, the yield of pentathionic acid can be made large and that of other polythionic acids quite small.

In addition to these two methods of preparation it has been shown that pentathionic acid is formed by the hydrolysis of sulphur monochloride (19, p. 266), as well as by leading sulphur vapor and water vapor through a heated tube (22). Of special interest in connection with this investigation

is the suggestion of Brugnatelli and Pelloggio (6) that oxidation of sulphur in the presence of moisture leads to the formation of pentathionic acid as an intermediate product in the formation of sulphuric acid. An interesting case of the occurrence of pentathionates in nature is reported by Day and Allen (9, pp. 115–118). These authors found that salt incrustations around hot springs near Lassen Peak, Shasta County, California, contained considerable amounts of soluble pentathionates.

Pentathionic acid has not been obtained in a pure state, although aqueous solutions containing 50–60 per cent of the acid may be prepared. It is a strong acid comparable to sulphuric acid and may be titrated with methyl-orange indicator. It is fairly stable in the presence of other strong mineral acids, but is at once decomposed by addition of an excess of sodium hydroxide solution, with separation of elementary sulphur in finely divided form, and this reaction forms the basis of a characteristic qualitative test for pentathionic acid, since no other oxygen acid of sulphur gives this test, with the possible exception of the recently prepared hexathionic acid (50). A less conclusive test is the formation of silver sulphide when a solution containing pentathionic acid is treated with ammoniacal silver-nitrate solution.

Among other reactions of pentathionates may be mentioned that with sodium sulphite forming sodium trithionate and thiosulphate, which has been used as a rapid titration method by Kurtenacker and Bittner (25). Hydrogen sulphide also rapidly decomposes pentathionic acid forming sulphur and water, according to Debus (10).

Preparation of potassium pentathionate and barium pentathionate.—In order to test the hypothesis that pentathionic acid is a factor in the toxic action of sulphur on fungus spores, it is desirable to prepare solutions of the acid from its purified salts, since the crude preparations obtained by the method of Wackenroder or of Salzer may contain a number of other compounds in addition to pentathionic acid. The potassium salt has been prepared by a number of investigators and its optical and crystallographic properties described by Fock and Klüss (15). Barium pentathionate has been prepared by Lenoir (29) and by Fordos and Gélis (18), and these authors note that the barium salt when precipitated by alcohol persistently retains small amounts of alcohol.

The procedure used in this investigation was the same as that described by Raschig (34, pp. 274–289). The final syrupy solution of pentathionic acid was freed from sodium pentathionate as described by him and treated with potassium acetate and acetic acid in alcohol. The potassium salt was recrystallized once from water containing 1 per cent sulphuric acid, washed with alcohol, and dried over calcium chloride. In the case of the barium salt, a concentrated solution of barium acetate, containing 3 per cent of free acetic acid was added to the pentathionic acid and barium sulphate filtered

off. On treating the filtrate with an equal volume of alcohol, the barium pentathionate separated in well-formed rectangular tablets. This salt was dissolved in water acidulated with acetic acid, and reprecipitated with alcohol. The proportion of potassium or of barium in these preparations was determined by ignition to constant weight with an excess of concentrated sulphuric acid and that of sulphur by oxidation with bromine and hydrochloric acid followed by precipitation as barium sulphate.

TABLE 3.—*Results of analyses of potassium pentathionate and barium pentathionate*

Potassium pentathionate			Barium pentathionate		
	Found	Calculated for $K_2S_5O_6.1\frac{1}{2}H_2O$		Found	Calculated for $BaS_5O_6.3\frac{1}{2}H_2O$
Potassium	21.67%	21.63%	Barium	30.21%	30.08%
Sulphur	44.16%	44.34%	Sulphur	35.30%	35.10%
Ratio K–S	2–4.97	2–5	Ratio Ba–S	1–5.01	1–5

The crystals dissolved in water, formed a clear solution and gave the qualtative tests for a pentathionate, *i.e.*, an immediate precipitation of sulphur with sodium hydroxide and a brownish black precipitate with ammoniacal silver nitrate. A 0.1-gram portion in 10 c.c. did not decolorize 1 drop N/10 iodine, indicating the absence of sulphites and thiosulphates, and gave no precipitate with barium chloride, indicating the absence of sulphates. The crystals (Figs. 1 and 2) were submitted for examination to C. W. Mason, of Cornell University, who reports as follows:

"Potassium pentathionate hemitrihydrate. Orthorhombic, (as described by Groth: Chemische Krystallographie **2**: 717. Leipzig, 1906). 2V about 65°, $v < \rho$, with the axial plane parallel to 010. Optically negative. Refractive indices by the immersion method: $\alpha = 1.570$; $\beta = 1.63 \pm$; $\gamma = 1.658$."

"Barium pentathionate, hydrated. As received: well-formed rectangular tablets, occasionally with their corners truncated by small bipyramid faces. The tablets are flattened parallel to the axial plane, so that only edge views exhibit interference figures. 2E is large, and the optical character is positive (+). Refractive indices by the immersion method: $\alpha = 1.620-$; $\beta = 1.640-$; $\gamma = 1.670$."

"The above tablets, placed in water, become covered by numerous small prismatic crystals. Recrystallized from water, in which the salt is very soluble, imperfect tapering four sided prisms with curved edges, very acute ends, and marked transverse cleavage, are obtained. These exhibit extinction varying from parallel to about 8° as a maximum. Interference figures

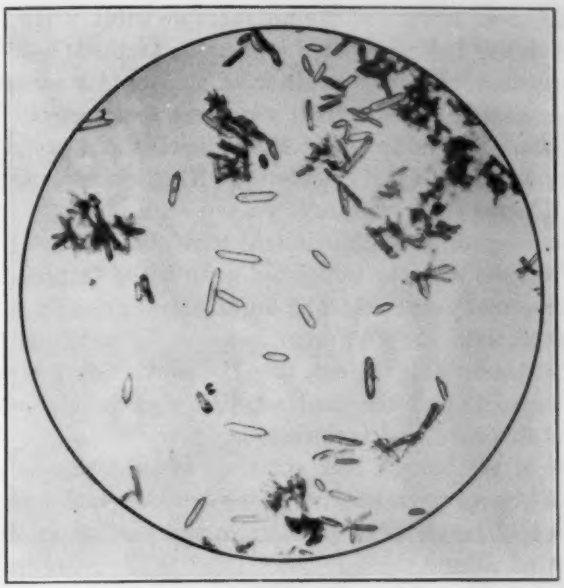

FIG. 1. Crystals of potassium pentathionate from aqueous solution by addition of alcohol.

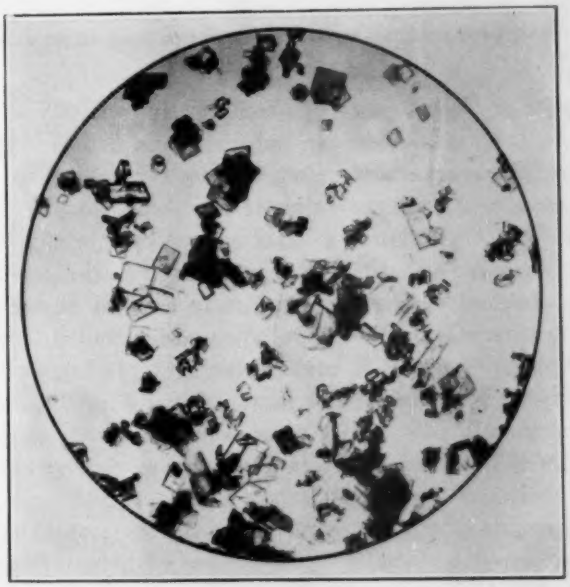

FIG. 2. Crystals of barium pentathionate from aqueous solution by addition of alcohol.

were not obtained on account of the unfavorable habit of the crystals. Approximate refractive indices, by the immersion method: $\alpha = 1.59$; $\beta = 1.67$; $\gamma = 1.75$. Recrystallized by the addition of alcohol to a concentrated aqueous solution, crystals like those from water are first formed, singly and in clusters. As more alcohol is added these dissolve and rectangular tablets appear, finally replacing them completely. This indicates the existence of two different degrees of hydration."

Solutions containing pentathionic acid were obtained by treating 1 gram of the potassium salt with the calculated quantity of tartaric acid required to liberate the pentathionic acid and form potassium acid tartrate, if the reaction were complete. It was found, however, by weighing the potassium acid tartrate which crystallized out, that the conversion was approximately 50 per cent complete and the final solution contained pentathionic acid, potassium pentathionate, and tartaric acid.

In the case of the barium salt, solutions of pentathionic acid were obtained by adding to a known solution of the salt the exact quantity of standard sulphuric acid required to precipitate the barium as sulphate. The latter was filtered off and the solution diluted to the concentration desired. The pentathionic acid solutions obtained in this manner were quite stable, did not deposit sulphur on standing, and still gave tests for pentathionic acid after keeping for a month.

The relative toxicity of pentathionic acid, sulphuric acid, and hydrogen sulphide

In this series of experiments, the comparative toxicity of pentathionic acid, sulphuric acid, and hydrogen sulphide was determined. Sulphuric acid was chosen for comparison because it is a typical strong mineral acid, as is pentathionic acid, but the sulphate ion shows no marked toxicity to fungus spores (7). Sulphuric acid is commonly present in commercial sulphur, and in greater quantities than pentathionic acid, and finally, it was used as a standard of comparison by Young and his coworkers (52, 53). Preliminary results with hydrogen sulphide are included, since the recent work of Marsh (30) appears to confirm the early findings of Polacci (33) that this substance is an important factor in the fungicidal action of sulphur. Hydrogen sulphide rapidly escapes from aqueous solutions exposed to the air. Hence it was necessary to perform the toxicity tests in a closed vessel. The hydrogen-ion concentration of the sulphuric acid and pentathionic acid solutions was determined with the antimony electrode (4, pp. 83, 84), because irregular results were obtained with pentathionic acid when the hydrogen electrode was used. The results of this series of experiments are presented in tables 4 to 8 and figures 3 to 10.

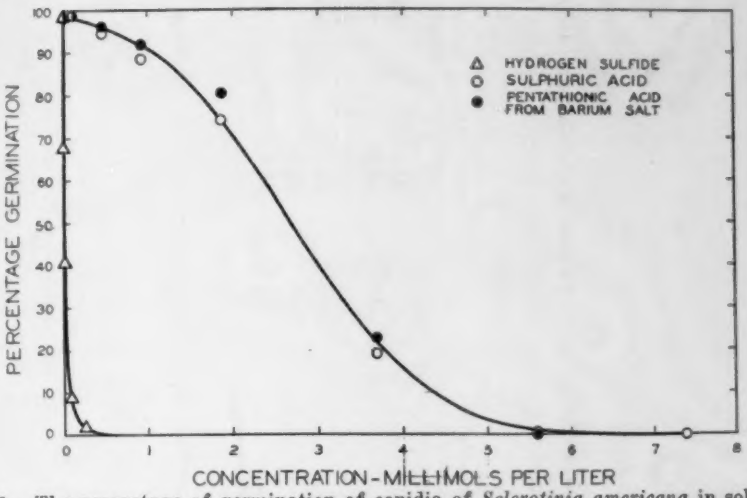

FIG. 3. The percentage of germination of conidia of *Sclerotinia americana* in solutions containing varying concentrations of H_2S, H_2SO_4 and of $H_2S_5O_6$ prepared from the barium salt.

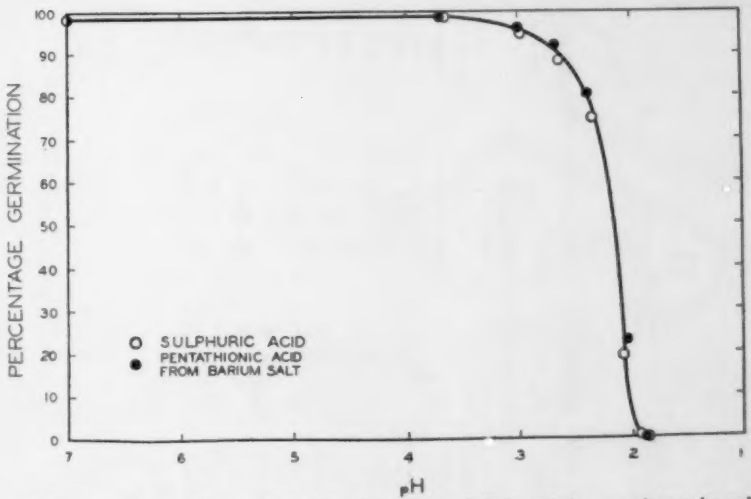

FIG. 4. The percentage of germination of conidia of *Sclerotinia americana* in solutions of H_2SO_4 and $H_2S_5O_6$, plotted against the pH of these solutions.

TABLE 4.—*The comparative toxicity of pentathionic acid and sulphuric acid solutions to the conidia of Sclerotinia americana*

Pentathionic acid (from barium salt)				Sulphuric acid			
Concentration (millimols per litre)	pH	Percentage germination	Germ-tube length (μ)	Concentration (millimols per litre)	pH	Percentage germination	Germ-tube length (μ)
Control	—	98.4	300	Control	—	98.4	300
0.092	3.70	98.6	300	0.092	3.65	98.7	320
0.462	3.00	96.0	250	0.462	2.98	94.7	225
0.930	2.67	91.9	175	0.930	2.64	88.2	150
1.860	2.38	80.3	100	1.860	2.35	74.9	80
3.696	2.04	22.9	40	3.696	2.07	19.3	35
5.604	1.88	0	0	5.604	1.92	0.5	25
—	—	—	—	7.392	1.86	0	0

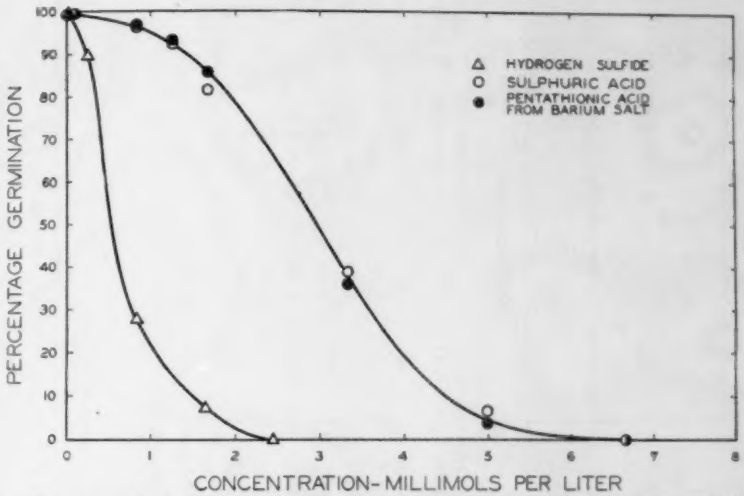

FIG. 5. The percentage of germination of conidia of *Botrytis* sp. (*cinerea* type) in solutions containing varying concentrations of H_2S, H_2SO_4 and of $H_2S_5O_6$ prepared from the barium salt.

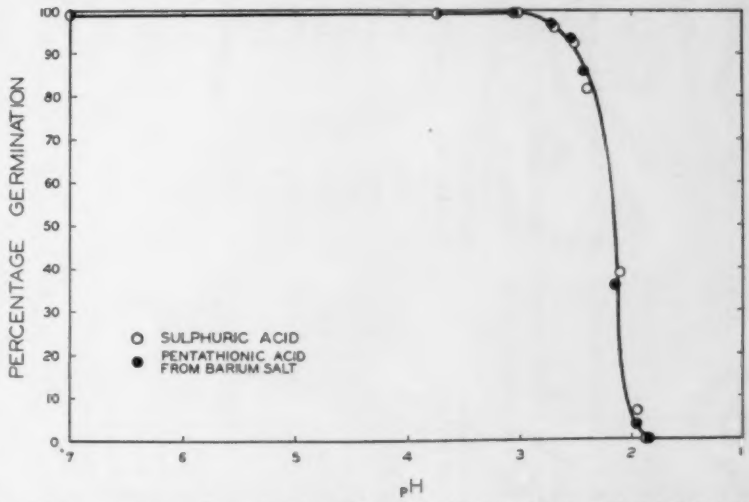

FIG. 6. The percentage of germination of conidia of *Botrytis* sp. (*cinerea* type) in solutions of H_2SO_4 and $H_2S_5O_6$, plotted against the pH of these solutions.

TABLE 5.—*The comparative toxicity of pentathionic acid and sulphuric acid solutions to the conidia of Botrytis sp. (cinerea type)*

Pentathionic acid (from barium salt)				Sulphuric acid			
Concentration (millimols per litre)	pH	Percentage of germination	Germ-tube length (μ)	Concentration (millimols per litre)	pH	Percentage of germination	Germ-tube length (μ)
Control	—	99.0	200	Control	—	99.0	200
0.084	3.75	99.3	200	0.084	3.75	99.3	200
0.418	3.06	99.3	200	0.418	3.03	99.3	200
0.835	2.72	96.8	150	0.835	2.70	96.0	150
1.254	2.54	93.2	100	1.254	2.52	92.2	100
1.669	2.43	85.7	85	1.669	2.40	81.5	75
3.332	2.15	35.9	45	3.332	2.11	38.9	50
4.998	1.95	3.4	25	4.998	1.95	6.3	30
6.664	1.85	0	0	6.664	1.87	0	0

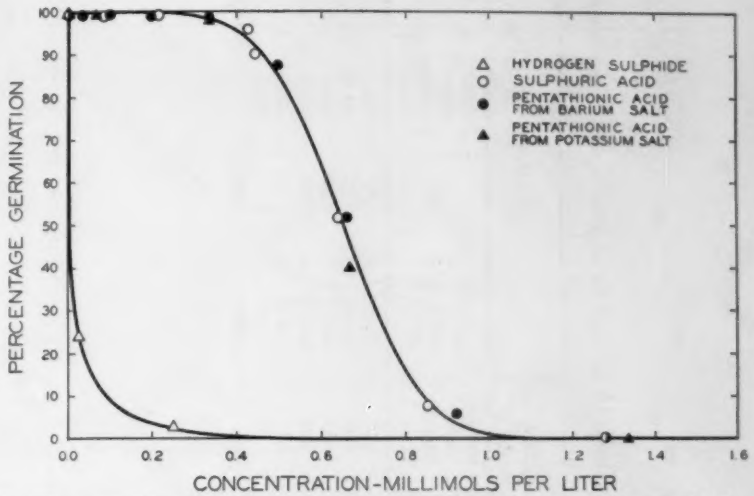

FIG. 7. The percentage of germination of conidia of *Macrosporium sarcinaeforme* in solutions containing varying concentrations of H_2S, H_2SO_4 and of $H_2S_5O_6$ prepared from the barium and potassium salts.

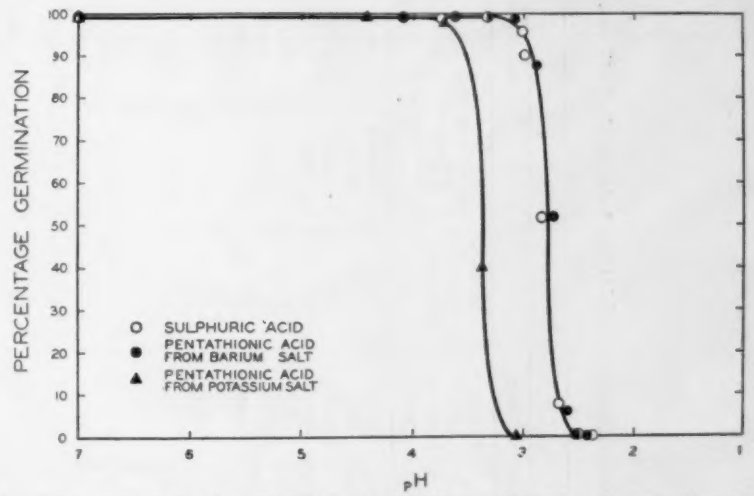

FIG. 8. The percentage of germination of conidia of *Macrosporium sarcinaeforme* in solutions of H_2SO_4 and $H_2S_5O_6$ plotted against the pH of these solutions.

TABLE 6.—*The comparative toxicity of pentathionic acid and sulphuric acid solutions to the conidia of Macrosporium sarcinaeforme*

Pentathionic acid								Sulphuric acid			
From barium salt				From potassium salt							
Concentration (millimols per liter)	pH	Percentage of germination	Germ-tube length (μ)	Concentration (millimols per liter)	pH	Percentage of germination	Germ-tube length (μ)	Concentration (millimols per liter)	pH	Percentage of germination	Germ-tube length (μ)
Control	—	99.3	400	Control	—	99.0	400	Control	—	99.3	400
0.033	4.08	99.1	500	0.006	5.50	99.0	400	0.084	3.75	98.8	425
0.099	3.62	99.2	500	0.064	4.42	99.0	400	0.214	3.34	99.0	400
0.199	3.33	99.0	500	0.333	3.73	97.7	250	0.426	3.02	95.7	300
0.332	3.07	98.7	500	0.667	3.40	40.0	120	0.437	3.00	90.0	300
0.497	2.88	87.7	300	1.333	3.08	0	0	0.640	2.83	51.6	125
0.663	2.73	51.8	200	—	—	—	—	0.853	2.68	7.5	30
0.924	2.60	5.9	30	—	—	—	—	1.280	2.51	0.2	15
1.280	2.53	0.2	15	—	—	—	—	1.706	2.38	0	0
1.710	2.42	0	0	—	—	—	—	—	—	—	—

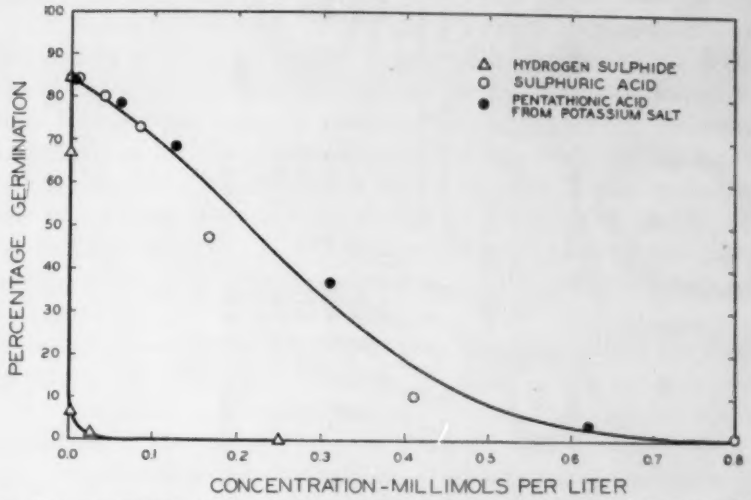

FIG. 9. The percentage of germination of uredospores of *Uromyces caryophyllinus* in solutions containing varying concentrations of H_2S, H_2SO_4 and of $H_2S_5O_6$ prepared from the potassium salt.

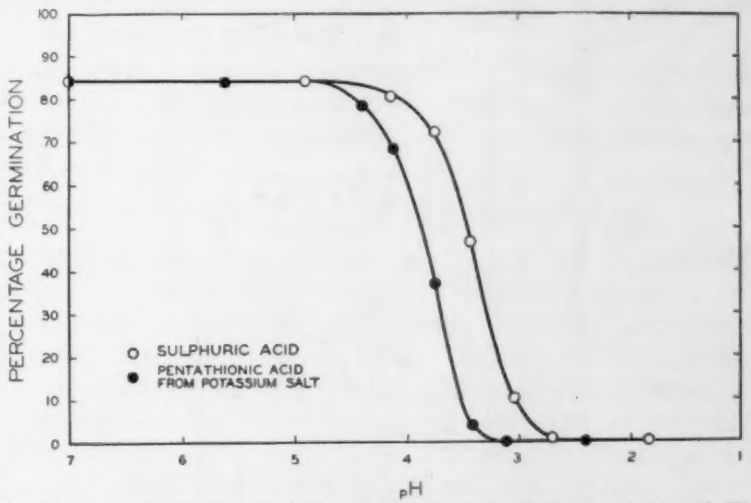

FIG. 10. The percentage of germination of uredospores of *Uromyces caryophyllinus* in solution of H_2SO_4 and $H_2S_5O_6$, plotted against the pH of these solutions.

TABLE 7.—*The comparative toxicity of pentathionic acid and sulphuric acid solution of the uredospores of Uromyces caryophyllinus*

Pentathione acid (from potassium salt)				Sulphuric acid			
Concentration (millimols per litre)	pH	Percentage of germination	Germ-tube length (μ)	Concentration (millimols per litre)	pH	Percentage of germination	Germ-tube length (μ)
Control	—	84.2	400	Control	—	84.2	400
0.006	5.60	83.8	400	0.008	4.90	84.2	400
0.062	4.40	78.1	300	0.041	4.15	80.0	300
0.124	4.12	68.5	200	0.082	3.75	72.7	200
0.311	3.76	36.9	150	0.163	3.45	46.9	150
0.622	3.43	3.9	50	0.408	3.05	10.1	75
1.245	3.12	0	0	0.816	2.71	0.8	25
6.224	2.42	0	0	8.157	1.84	0	0

Since the results obtained with a given fungus, using sulphuric and pentathionic acids, are in no case significantly different, as was also found by Roach and Glynne (38), working with *Synchytrium endobioticum*, a single curve has been drawn through all the points obtained. This curve was derived by plotting the points on probability paper (47, pp. 263–270) and drawing the best straight line through the points by the method of least squares. The sigmoid curve obtained in this way, which may be considered as the integrated form of a probability curve, appears to fit the data quite well. The theoretical significance of such a curve in relation to toxicity experiments has been discussed by Brooks (5, p. 78) and Smith (42, pp. 31–34; 43, pp. 340–341). It will be observed that in every case hydrogen sulphide exhibits much greater toxicity than either sulphuric acid or pentathionic acid.

When the percentage of germination is plotted against pH for sulphuric and pentathionic acids, no evidence is obtained for an optimum zone of toxicity. The solutions show no effect until a rather high acidity is reached, which varies for the different species of fungi, and the curves then drop sharply, the point of complete inhibition of germination being reached quite rapidly.

The difference in effect of the pentathionic acid solutions made from the potassium salt and those made from the barium salt may perhaps be ascribed to the content of foreign material in the former, namely, potassium pentathionate and tartaric acid, which contribute much to the total molecular concentration but little to the acidity.

An interesting observation frequently made was that discarded solutions of pentathionic acid became contaminated with a species of Penicillium, which grew luxuriantly in these solutions. This was not the case with the sulphuric acid solutions.

The toxicity of the salts of pentathionic acid

Although, according to Williams and Young, free pentathionic acid exhibits marked toxicity, these authors state that the neutral salts are nontoxic (52, p. 361). Accordingly, a study has been made of the toxicity of potassium pentathionate to the conidia of *Sclerotina americana*, in distilled water, in an acid buffer solution, and in a solution to which sufficient sodium hydroxide was added to cause incipient decomposition of the potassium pentathionate. The buffer used was the phthalate—NaOH buffer of Clark and Lubs (8) pH 4.6 diluted to ¼ the recommended strength. The results are shown in tables 9 and 10.

Potassium pentathionate in distilled water was entirely nontoxic at the concentration employed. When the salt is placed in an acid buffer a certain amount of free pentathionic acid must be formed, but, even under

TABLE 8.—*The toxicity of hydrogen sulphide to the conidia of Botrytis sp. (cinerea type), Macrosporium sarcinaeforme, Sclerotinia americana and to the uredospores of Uromyces caryophyllinus*

Concentration (millimols per litre solution)	*Botrytis* sp. (*cinerea* type)		*Macrosporium sarcinaeforme*		*Sclerotinia americana*		*Uromyces caryophyllinus*	
	Percentage of germination	Germ-tube length (μ)	Percentage of germination	Germ-tube length (μ)	Percentage of germination	Germ-tube length (μ)	Percentage of germination	Germ-tube length (μ)
Control	99.2	200	99.4	400	98.8	400	84.2	400
0.0002	—	—	—	—	—	—	66.8	75
0.0025	—	—	—	—	67.4	150	6.4	30
0.0250	99.4	225	24.1	100	40.5	100	1.3	15
0.0840	—	—	—	—	8.5	50	—	—
0.2500	89.5	175	2.6	50	1.5	25	0	0
0.4600	—	—	—	—	—	—	—	—
0.8300	27.8	75	—	—	—	—	—	—
1.6500	7.2	50	—	—	—	—	—	—
2.4600	0.1	15	0	0	—	—	0	0

TABLE 9.—*The toxicity of potassium pentathionate solutions to the conidia of Sclerotinia americana*

Solution	Percentage of germination	Germ-tube length (μ)
Control	99.2	500
0.10% $K_2S_5O_6 \cdot 1\frac{1}{2}$ H_2O in redistilled water	99.4	500
0.01% $K_2S_5O_6 \cdot 1\frac{1}{2}$ H_2O in potassium acid phthalate—NaOH buffer, pH 4.6	99.4	500
0.10% $K_2S_5O_6 \cdot 1\frac{1}{2}$ H_2O in potassium acid phthalate—NaOH buffer, pH 4.6	99.1	500
0.50% $K_2S_5O_6 \cdot 1\frac{1}{2}$ H_2O in potassium acid phthalate—NaOH buffer, pH 4.6	99.2	500
Potassium acid phthalate—NaOH buffer, pH 4.6	99.4	500

TABLE 10.—*The toxicity, to the conidia of Sclerotinia americana, of colloidal sulphur formed from solutions of potassium pentathionate and sodium hydroxide*

Solution	pH	Percentage of germination	Germ-tube length (μ)
Control	—	98.5	275
95 c.c. 0.5% $K_2S_5O_6 \cdot 1\frac{1}{2}$ H_2O + 5 c.c. N/10 NaOH	6.72	0	0
ditto, diluted 1–10	6.40	62.5	75
5 c.c. N/10 in 100 c.c. redistilled H_2O	11.14	83.9	200
ditto, diluted 1–10	10.49	97.6	350

these conditions, no toxicity was exhibited, although the pH value of 4.6 lies within the range of maximum toxicity according to Young (55, p. 410).

In the case of the solutions to which sodium hydroxide was added, due to partial decomposition, colloidal sulphur was formed, and these solutions were highly toxic.

THE TOXICITY OF WATER EXTRACTS FROM SULPHUR

Williams and Young (52, p. 359) have stated that pentathionic acid is found in filtered water extracts from sulphur. In another place (57, p. 19) the same authors say that this acid is adsorbed quite completely by the sulphur particle so that none can be washed off. According to our experience most samples of sulphur give water extracts which respond to tests given by pentathionic acid. (a) They form a brownish black precipitate of silver sulphide with ammoniacal silver nitrate. (b) When hydrogen sulphide is passed through the extracts for several minutes, colloidal sulphur is formed. (c) There is a slight precipitate formed when the extracts are made alkaline with sodium hydroxide. None of the extracts

examined gave the methylene blue test for hydrogen sulphide. The reactions obtained were, however, not very distinct, and other substances than pentathionic acid might have given each of them; we are only justified in saying, therefore, that there is a strong probability of the existence of traces of pentathionic acid in the water extracts but not an absolute certainty.

The toxicity of water extracts from several samples of sulphur has been determined. These extracts were made by triturating 100 gram portions of sulphur in a mortar with 100 c.c. of distilled water and filtering the mixture. Three of the sulphur samples were obtained from a well-known firm dealing in chemical reagents and correspond to the sulphur preparations listed in the U. S. Pharmacopeia and others were two well-known brands of commercial 300-mesh dusting sulphur. One of the latter gave an alkaline water extract which showed the presence of calcium when tested with ammonia and ammonium oxalate. None of the extracts tested showed any toxicity to conidia of *Sclerotinia americana* when prepared as described above. The results appear in table 11.

TABLE 11.—*The toxicity of water extracts from various kinds of sulphur to the conidia of Sclerotinia americana*

Solution	pH	Percentage of germination	Germ-tube length (μ)
Control	——	99.3	900
Water extract from Sulphur Lotum	6.0	99.5	900
" " " Sulphur Praecipitum	6.4	99.4	800
" " " Roll Sulphur	6.2	99.3	900
Control	——	97.6	175
Water extract from commercial dusting sulphur (A)	4.2	98.2	180
Water extract from commercial dusting sulphur (B)	8.6	98.8	225

THE TOXICITY OF SULPHUR DUST BEFORE AND AFTER TREATMENT TO REMOVE ACIDS

When it is desired to compare two samples of sulphur and to determine the effect of some factor on their toxicity, as, for example, the presence or absence of pentathionic acid, it is necessary that the samples should be alike in other respects. One factor that might be expected to influence the toxicity is the particle size of the material. Roll sulphur was ground and sieved to furnish four samples whose particles varied from 33 to 285 μ in diameter. The average diameter for each lot was determined by micro-

metric measurement of the particles. The toxicity to conidia of *Sclerotinia americana* was determined in quadruplicate tests on each sample. The results are shown in table 12.

TABLE 12.—*The relation between the particle size and toxicity of a sulphur dust to the conidia of Sclerotinia americana*

Treatment	Mean diameter of particle (μ)	Percentage of germination
Control	—	97.6
Ground Roll Sulphur	285	62.8
" " "	142	47.2
" " "	60	29.1
" " "	33	20.7

It will be seen that the toxicity increases to a marked degree as the particles decrease in size, and therefore particle size must be considered in the evaluation of sulphur dusts as fungicides.

If the toxic factor of sulphur were pentathionic acid, it would be reasonable to expect a difference in toxicity between sulphur, treated in such a way as to destroy any traces which might exist, and the original sample. Accordingly, a sample of 300-mesh dusting sulphur which gave a marked test with ammoniacal silver nitrate, was divided into two portions. One of these was triturated in a mortar with one per cent sodium hydroxide solution and allowed to remain in contact with the solution overnight. The next morning it was filtered with suction and thoroughly washed until the washings were neutral to litmus. Just before use, a portion was extracted with distilled water and the extract tested for pentathionic acid with ammoniacal silver nitrate. None was found. Comparative toxicity tests, using the conidia of *Sclerotinia americana*, were then made on the two samples in triplicate, 5000 spores being counted. The results of this experiment are shown in table 13.

TABLE 13.—*The comparative toxicity, to Sclerotinia americana conidia, of sulphur dust before and after treatment to remove pentathionic acid*

Treatment	Percentage of germination	Germ-tube length (μ)
Control	98.0	400
300-mesh sulphur untreated; with original pentathionic acid content	64.7	100
300-mesh sulphur treated to remove content of pentathionic acid	64.4	100

There is no significant difference in toxicity between sulphur treated to remove pentathionic acid and untreated sulphur.

SUMMARY

1. The various theories that have been advanced to account for the fungicidal action of sulphur have been briefly reviewed, with especial emphasis on the pentathionic acid hypothesis of Young.

2. An improved technique has been employed for the laboratory determination of fungicidal activity, by means of spore-germination tests.

3. The spores of four representative pathogenic fungi were used, namely, *Botrytis* sp. (*cinerea* type), *Macrosporium sarcinaeforme*, *Sclerotinia americana*, and *Uromyces caryophyllinus;* these exhibit varying degrees of sulphur sensitivity.

4. The accuracy attained in these tests has been determined, and defined in terms of percentage of germination and odds of significance.

5. The chemistry of pentathionic acid has been discussed, and the preparation, analysis, and properties of potassium and barium penathionates have been described. Pentathionic acid solutions have been prepared from these salts.

6. The comparative toxicity of pentathionic acid, sulphuric acid, and hydrogen sulphide to the four fungi has been determined. It has been found that pentathionic and sulphuric acids, both typical strong mineral acids, exhibit identical toxicity within the error of the experiment. The toxicity of these acids is apparently due to the hydrogen ion, and a comparatively high concentration is required for its manifestation. Hydrogen sulphide is from 6 to 200 times as toxic.

7. When percentage of germination is plotted against concentration of a toxic agent, a sigmoid curve is obtained. This curve appears to be the integrated form of a normal distribution curve, which perhaps indicates the distribution of resistance among the individual spores used.

8. The neutral salts of pentathionic acid were found to be nontoxic to conidia of *Sclerotinia americana*, except when treated with sodium hydroxide, which destroys the pentathionic and forms colloidal sulphur.

9. It has been found that most samples of sulphur give water extracts that respond to qualitative tests for pentathionic acid, but these extracts were not toxic under the conditions of experiment.

10. The particle size of sulphur dusts is an important factor in their toxicity and must be considered in comparing one preparation with another. The toxicity increases with the fineness of subdivision.

11. A commercial 300-mesh dusting sulphur, treated with sodium hydroxide to remove pentathionic and sulphuric acids, did not differ in toxicity from the same preparation before treatment.

12. It is therefore concluded that pentathionic acid is not a factor of importance in the fungicidal action of sulphur.

BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH, INC.,
YONKERS, NEW YORK.

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EFFECT ON PLANTS OF CYANIDE FUMIGATION FOLLOWING SPRAYING WITH BORDEAUX MIXTURE

O. Butler and R. R. Jenkins

Woglum[1] has on several occasions called attention to the danger of cyaniding citrus trees sprayed with Bordeaux mixture. The lower branches of the trees are sometimes sprayed with Bordeaux mixture and the fungicide in paste form is also applied to the trunk and branches. When the mixture is applied to the trunk the trees can be fumigated immediately without injury, but if it is applied to the branches, also, or to the branches only, or the tree has been sprayed, then fumigation can not safely be given until six months have elapsed. Injury has been observed even when fumigation was delayed eleven months. Woglum suggests that the injury produced by cyanide fumigation following an application of Bordeaux mixture is due to the formation of a copper cyanide.

Guba[2] has found that cucumber and tomato plants sprayed with Pyrox or Bordeaux mixture or dusted with copper-lime dust and then subjected to cyanide fumigation are injured. He ascribes the injury to the formation of cupric cyanide, an unstable salt decomposing with liberation of cyanogen to form cuprous cyanide, and concludes that plants exposed to hydrocyanic-acid gas should never be sprayed antecedently with a copper fungicide.

The Bordeaux mixture used in citrus spraying is alkaline; the mixtures and copper-lime dust employed by Guba are alkaline. It has seemed to us desirable, therefore, to study the effect of the ratio copper sulphate to quick lime, used in preparing a Bordeaux mixture, on the injuriousness of cyanide fumigation, and to subject to experimental verification the suggestion of Guba that hydrocyanic-acid gas combines with the copper to form unstable cupric cyanide. We shall here present successively: (1) The effect of ratio copper sulphate to quick lime on toxicity of hydrocyanic-acid gas; (2) the effect of wetting foliage after cyanide fumigation; and (3) the chemical changes involved when Bordeaux mixtures of various types react with hydrocyanic-acid gas.

I

In our experiments we used sodium cyanide at the rate of 0.20 oz. per 1000 cubic feet, the hydrocyanic-acid gas being generated by mixing the

[1] Woglum, R. S. Fumigation of citrus trees. U. S. Dept. Agr. Farmers' Bul. 923. 1918. Fumigation of citrus plants with hydrocyanic acid: Conditions influencing injury. U. S. Dept. Agr. Bul. 907. 1920. Fumigation of citrus trees for control of insect pests. U. S. Dept. Agr. Farmers' Bul. 1321. 1923.

[2] Guba, E. F. Injury to glass-house plants from hydrocyanic acid gas following the application of copper fungicides. Phytopath. 16: 633–634. 1926.

TABLE 1.—*Effect of composition of Bordeaux mixture on injury to plants following cyanide fumigation*

Subjected plant	No. of experiments	Plants not sprayed before cyaniding	Extent of injury following fumigation. Plants sprayed before cyaniding with Bordeaux mixture						
			1:0.2	1:0.5	1:1	1:2	1:4	1:6	Milk of lime
Sunflower	5	none	trace	v. slight	bad	slight	trace	trace	trace
Tomato	5	trace	v. slight	slight	v. marked	marked	slight	v. v. slight	trace
Bean	4	none	slight	slight	bad	marked	slight	v. slight	v. slight
Cucumber	4	none	trace	v. v. slight	v. bad	slight	trace	none	none
Castor-oil plant	4	none	trace	trace	slight	v. slight	none	none	none
Potato	3	none	none	trace	marked	marked	v. v. slight	trace	none

sodium cyanide, concentrated sulphuric acid, and water in the following proportions:

Sodium cyanide, 2 parts; sulphuric acid conc. C. P., 1½ parts; water, 2 parts.

The plants were cyanided for approximately 12 hours, *i.e.*, from one hour after sundown to daybreak and at a mean temperature of approximately 18° C. The plants in each series of an experiment were sprayed in triplicate and arranged on the benches in sequence so as to obtain as nearly as possible equal exposure to the hydrocyanic-acid gas. The sprays were applied the same day the plants were cyanided but sufficiently early to assure the foliage being dry before sundown. The Bordeaux mixtures contained 1 per cent copper sulphate and were prepared in the following ratios of cupric sulphate to calcic oxide 1:0.2, 1:0.5, 1:1, 1:2, 1:4, and 1:6. The mixture prepared in the ratio 1:0.2 was made with limewater and the requisite strength in copper sulphate obtained by allowing the mixture to settle and decanting. The other mixtures were made with milk of lime of the required strength. Besides the Bordeaux mixtures, milk of lime containing 1 per cent of calcic oxide was used.

The results obtained are summarized in table 1.

The data presented in the table show unmistakably that the amount of lime present in the Bordeaux mixture determines to a very marked degree the resultant injury. As the ratio of copper sulphate to quick lime is raised injury increases and then decreases for all the plants employed in the experiment. The data show that a 1:1 mixture, which is the one most frequently used in the United States, is, in general, the most injurious. In the case of the potato, however, in two out of the three experiments performed the 1:2 mixture proved more injurious. In the case of the bean the mixtures of the two ratios were equally injurious once; in the case of the tomato the 1:2 mixture was more injurious in one fifth of the experiments; but, for the other plants, the 1:2 mixture was never more injurious than the 1:1 mixture. Attention should be drawn also to the fact that the change in relative position of plants sprayed with Bordeaux mixture 1:1 occurs only in those instances where the injury produced by each type of mixture approximates rather closely that of the other as a glance at the data presented in table 2 will show, but has nothing to do with the sensitivity of the plant, since the castor bean, the most resistant of those employed, shows in round numbers twice the injury when a 1:1 mixture is used than it does when a 1:2 mixture is applied, and the cucumber, extremely sensitive to cyanide-fumigation following spraying, exhibits a like effect. To consider further the data presented in table 1, it will be noted that plants sprayed with neutral Bordeaux mixture and the mixture highest in lime suffer little injury when cyanided, the former being somewhat more

TABLE 2.—*Relative injuriousness of cyanide fumigation to plants sprayed with Bordeaux mixtures containing copper sulphate and quick lime in the ratios of 1:1 and 1:2, respectively*

Subjected plant	No. times 1:2 mixture proved more injurious than 1:1 mixture	Relative percentage of injury caused by	
		1:1 mixture	1:2 mixture
Sunflower	0	100	58
Bean	¼	100	77
Cucumber	0	100	47
Tomato	⅛	100	84
Castor-oil plant	0	100	54
Potato	⅜	100	85

injurious. Plants sprayed with milk of lime show no more injury following cyanide fumigation than do the nonsprayed plants. Lime, in and of itself, therefore, is not injurious.

FIG. 1. Bean plants sprayed with 1 per cent Bordeaux mixture 1:1, afternoon of May 17, and cyanided from sunset the same day to sunrise May 18. During the late afternoon of May 18 the foliage of the plant on the right of the figure was sprayed with distilled water and placed in a moist chamber over night. Photographed May 20. The apical leaves of the plant on the left are badly scorched and one cotyledonary leaf shows peripheral scorching. The plant on the right shows more serious injury, both cotyledonary leaves are badly scorched and curled, and the apical leaves are also seriously injured. Wetting the foliage has noticeably increased the injury due to cyanide fumigation.

It will also be observed that neutral Bordeaux mixture causes but little more injury than milk of lime. We may conclude, therefore, that since the copper precipitate in a neutral mixture has the same composition as the precipitate in freshly made alkaline washes, basic-copper sulphate, in and of itself, is not injurious. To produce injury an excess of calcium hydrate is required. But, in the case of the alkaline Bordeaux mixtures employed by the writers, the mother liquors give identical reactions; hence, it may be further concluded that the presence of insoluble calcium hydroxide in definite proportion to copper sulphate determines the degree of injury following cyanide fumigation.

II

The effect of cyanide fumigation following spraying with the Bordeaux mixtures described in the previous section is materially modified by the after treatment given the plants. When the foliage of sprayed and cyanided plants is wetted with water a day or so after the exposure to hydrocyanic-acid gas and is kept moist over night, the injury originally produced by 1:0.2, 1:0.5, and 1:1 mixtures is not markedly changed, but the 1:4 and 1:6 mixtures show extreme toxicity. In figures 1 to 6 is shown the effect

FIG. 2. Bean plants sprayed with 1 per cent Bordeaux mixture 1:6 but otherwise given same treatment as those illustrated in figure 1. The plant shown on the left is uninjured; the one on the right, the foliage of which was wetted, is dead.

produced by wetting the foliage of bean and cucumber plants previously sprayed with Bordeaux mixture 1:1 and 1:4 or 1:6, and cyanided.

FIG. 3. Cucumber plants sprayed with 1 per cent Bordeaux mixture 1:1 and cyanided. The younger leaves are scorched. Compare with figure 4.

In table 3 are presented the data obtained in an experiment designed to show the effect produced by wetting the foliage of sprayed and cyanided plants. On the late afternoon of the day following cyanide fumigation, the plants were divided into two sets. In one of the sets the foliage of the plants was allowed to remain dry; in the other, it was wetted and kept moist over night.

The data presented show clearly that Bordeaux mixtures high in lime can not be applied to plants subject to a cyanide-fumigation régime unless means are provided to keep the foliage dry at all times. Bordeaux mixtures prepared with copper sulphate-quick lime ratios of 1:4 and 1:6, and which are so poisonous when wetted following cyanide fumigation, presumably retain their toxic properties indefinitely. On the other hand, a neutral

TABLE 3.—*Effect of composition of Bordeaux mixture on the injury produced by wetting with water following cyanide fumigation*

Subjected plant	Treatment of foliage	Injury to plants sprayed before cyaniding with Bordeaux mixtures in the following ratios:			
		1: 0.2	1: 1	1: 4	1: 6
Cucumber	not wetted	none	marked	none	none
	wetted	slight	marked	very bad	very bad
Bean	not wetted	v. slight	bad	none	none
	wetted	slight	bad	very bad	very bad
Buckwheat	not wetted	none	none	none	none
	wetted	none	v. slight	very bad	very bad
Sunflower	not wetted	none	marked	none	none
	wetted	v. slight	marked	very bad	very bad

Bordeaux mixture may be used with safety and, judging from an experiment made with tomatoes, we presume that, in practice, Bordeaux mixtures in which the copper sulphate-quick lime ratio was 1: $\frac{1}{4}$ could be safely employed.

III

When hydrocyanic acid gas is passed into a Bordeaux mixture the nature of the resultant precipitate depends on the ratio of cupric sulphate to calcic oxide in the mixture. The color of the basic copper sulphate is rapidly discharged and the changes indicated in table 4 are obtained.

TABLE 4.—*Effect of composition of Bordeaux mixture on the reaction with hydrocyanic acid gas*

Ratio of $CuSO_4 5H_2O$ to CaO	Color of solution and of precipitate	
	At beginning	After 24 hours
1: 0.2	solution, colorless precipitate, yellowish green	solution, colorless precipitate, white
1: 0.5	solution, pink precipitate, white	solution, slightly yellow precipitate, dirty white
1: 1	solution, light brown precipitate, brownish green	solution, dark brown precipitate, yellowish brown
1: 2	solution, brown precipitate, yellowish brown	solution, dark brown precipitate, reddish brown
1: 4	solution, light yellow precipitate, white	solution, light brown precipitate, yellowish brown
1: 6	solution, colorles precipitate, white	solution, colorless precipitate, white

It will be noted that those Bordeaux mixtures which are more especially toxic to plants following cyanide fumigation are those in which the resultant precipitate is a shade of brown; while for those that are not toxic, *i.e.*, mixtures in which the ratio of copper sulphate to quick lime is 1: 0.2

and 1:6, respectively, it is white. The brown precipitates, washed in several changes of distilled water and spread on glass plates, give off cyanogen;

FIG. 4. Cucumber plants sprayed with 1 per cent Bordeaux mixture 1:4 and cyanided. Compare with plants shown in figure 3.

the white precipitate, washed and spread on glass plates, do not. The brown precipitates possess the properties of cupric cyanide. The white precipitates have the property of cuprous cyanide in the case of the 1:0.2 mixture, but, in the 1:6 mixture, we believe a double cyanide of copper and lime is formed, for the precipitate washed with water gives an alkaline solution containing all the copper and an abundance of lime in solution. It remains now to show that the Bordeaux mixtures that are toxic following cyanide fumigation actually combine with hydrocyanic-acid gas and gradually decompose with formation of cyanogen. This may easily be done in the following manner: The mixtures are sprayed on glass slides, dried, and exposed in the greenhouse to the cyanide fumigation given plants, *i.e.*, in

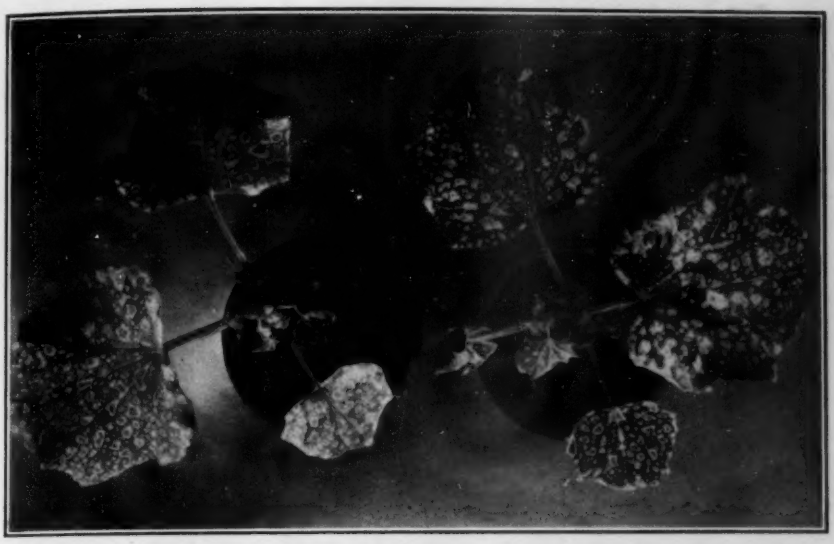

FIG. 5. Cucumber plants sprayed with 1 per cent Bordeaux mixture 1:1 and cyanided. On the afternoon of the day following fumigation the foliage of the plant on the right was wetted with distilled water and the plant placed in a moist chamber over night. The photograph was taken 24 hours later. Wetting the foliage has intensified the injury produced. Compare with figure 6.

our experiments, 0.20 oz. of sodium cyanide per 1000 cubic feet, and 12 hours exposure. The slides after cyaniding are allowed to air for a while and are then placed in petri dishes with a drop of water. Slips of filter paper are cut to the size of the glass slides, dipped in an alkaline picrate solution,[3] drained, laid on clean slides, and supported over the sprayed slides with a clearance of 2 mm. The petri dishes were then covered and allowed to stand 24 hours. After the paper was exposed for the length of time described it was rapidly dried and the colors matched to Ridgway's Standards.[4]

When a soluble cyanide is added to an alkaline picrate solution a salt of isopurpuric acid is formed which gives the solution a reddish brown color. In the presence of cyanogen the test paper gradually changed from pure yellow to shades of orange as the amount of cyanogen given off increased. In the absence of cyanogen the color of the paper was strontian yellow in the presence of increasing amounts of cyanogen the colors noted were, in order, wax yellow, primuline yellow, yellow ocher, ochraceous buff, and ochraceous orange.

[3] The solution was prepared according to the formula of R. G. Smith. A method for the quantitative determination of cyanide in small amounts. Jour. Amer. Chem. Soc. 51: 1171–1174. 1929.

[4] Ridgway, R. Color standards and color nomenclature. Washington, 1912.

TABLE 5.—*Effect of composition of Bordeaux mixture on the discharge of cyanogen following fumigation with hydrocyanic acid gas*

Mixture	Color of alkaline picrate after an exposure of		
	6 hours	12 hours	24 hours
Bordeaux 1:0.2	strontian yellow	strontian yellow	strontian yellow
do 1:0.5	strontian yellow	strontian yellow	primuline yellow
do 1:1	yellow ocher	yellow ocher	yellow ocher
do 1:2	wax yellow	primuline yellow	ochraceous orange
do 1:4	strontian yellow	strontian yellow	ochraceous buff
do 1:6	strontian yellow	strontian yellow	strontian yellow
Calcium hydrate 1% CaO	strontian yellow	strontian yellow	strontian yellow
Witness	strontian yellow	strontian yellow	strontian yellow

The results of one of the experiments are presented in table 5 and show conclusively that Bordeaux mixture made with a 1:1 ratio of copper sulphate to quick lime gives off cyanogen in largest amount and most rapidly. In the case of the 1:2 mixture the evolution of cyanogen is much slower than in the 1:1 mixture; in fact, after the lapse of 24 hours, a 1:2 Bordeaux mixture has given off only as much cyanogen as a 1:1 mixture in 6 hours. Bordeaux mixtures in which the ratio of copper sulphate to quick lime is 1:4 and 1:0.5, respectively, evolve cyanogen very slowly; but neither a 1:0.2 nor a 1:6 mixture, or milk of lime, gives off detectable amounts. Now, since calcium cyanide decomposes in moist air, it is clear that this salt does not form. It is also evident that cupric cyanide does not form in either a 1:0.2 or 1:6 Bordeaux mixture. We have already shown that a 1:0.2 Bordeaux mixture is not toxic following cyanide fumigation when the foliage is wetted and does not therefore contain a soluble cyanide. On the other hand, Bordeaux mixture in which the ratios of copper sulphate to quick lime are 1:1, 1:2, 1:4, and 1:6 contains soluble cyanide in increasing amounts, and when the foliage of plants sprayed with these mixtures and fumigated is wetted the washes highest in lime cause death; the others result in increased injury. (Figs. 1, 2, 5, 6.)

SUMMARY

1. The formation of cupric cyanide in a Bordeaux mixture exposed to cyanide fumigation is determined by the ratio of copper sulphate to quick

FIG. 6. Cucumber plants sprayed with 1 per cent Bordeaux mixture 1:6 and cyanided. On the afternoon of the day following fumigation the foliage of the plant on the right was wetted with distilled water and the plant placed in a moist chamber with the plant similarly treated and shown in figure 5. The photograph was taken 24 hours later. The plant on the left, the foliage of which was kept dry following fumigation, is uninjured; the plant on the right, the foliage of which was wetted, is dead. Compare with figure 5.

lime used in making the mixture. Cupric cyanide does not form when the ratio employed is 1:0.2 and in negligible amounts only when the ratio is 1:4, or higher.

2. In a 1:0.2 mixture insoluble cuprous cyanide is formed; in a 1:6 mixture a soluble double cyanide. In mixtures of ratios greater than 1:1 but less than 1:6 the amount of cupric cyanide formed decreases with increase in calcium hydrate, and the double cyanide becomes more abundant.

3. A Bordeaux mixture, forming with hydrocyanic acid gas a double cyanide, in injurious if the sprayed and cyanided plants are wetted.

4. A neutral Bordeaux mixture, or an approximately neutral mixture, is the only type to be recommended when the sprayed plants are to be subjected to cyanide fumigation. It should then be used only on plants that are no more sensitive to soluble copper than is the tomato.

NEW HAMPSHIRE AGRICULTURAL EXPERIMENT STATION,
DURHAM, NEW HAMPSHIRE

THE RELATION OF PROTOCATECHUIC ACID TO DISEASE RESISTANCE IN THE ONION[1]

H. R. Angell, J. C. Walker, and Karl Paul Link

INTRODUCTION

Relatively greater resistance to certain diseases has long been known in those varieties of onion in which red or yellow pigment is produced in the bulb scales as they approach maturity. It is especially noticeable in the case of smudge, caused by *Colletotrichum circinans* (Berk.) Vogl., and neck rots caused by *Botrytis* spp. The nature of this resistance was first studied by Walker (5, 6). It was found that in the case of the colored onions a water-soluble toxic substance (or substances) occurred in the dry outer scales of the bulbs. In this toxic solution the growth of the smudge organism was checked, the tips of young germ tubes commonly ruptured, or the spores were killed without germinating. It was thus interpreted that during periods when moisture was present upon the bulbs and when infection by the smudge organism ordinarily occurred the toxic substance (or substances) present in the tissue diffused into the water and precluded further advance by the fungus, if it were present. No such toxic effects were found in the dry outer scales of white bulbs, which were very susceptible to smudge.

Further studies (8, 9) showed that the extracts of outer colored onion scales were toxic not only to the smudge and neck-rot organisms but also to several other fungi tested, some of which were pathogenes of the onion and others were not. *Aspergillus niger* was the only organism tested the growth or germination of which was not greatly inhibited. Correlation of resistance with the production of red or yellow pigments was found only in the case of those organisms which normally penetrate the onion in such a way as to encounter the dry outer scales before entry. Thus, in the case of Fusarium bulb rot, where the organism enters by way of the root scars or of the basal tissue of the bulb, no resistance was noted, even though the parasite was inhibited when exposed to the scale extract.

It was further shown that the toxic substance is readily soluble only from the dry outer scales and that it functions as a resistant property of these scales only as it diffuses from them. The inner fleshy scales, even though colored, are readily attacked by the smudge fungus when the

[1] This study is the result of cooperative investigations between the Department of Plant Pathology, University of Wisconsin, and the Office of Horticultural Crops and Diseases, Bureau of Plant Industry. The initial chemical investigations were performed by Angell. The final steps in the isolation and identification of the toxic compound were carried out by Link.

inoculum is applied directly to them. The reason for this is not known, but two possible explanations are offered. It may be readily demonstrated that as the fungus penetrates the cuticle of the fleshy scales the pigment which is confined to the epidermal cell rapidly disappears, apparently before the hyphae have traversed the subcuticular wall to enter the cell lumen. May the toxic substance not also be destroyed with the pigment? Another possibility, still unsettled, is whether the pigment and the toxic substance are identical. If they are not the same, is the toxic substance absent from the fleshy scales, and does it appear only in the outer scales after they have dried? In any case, it is certain that the outer dry scales containing the readily diffusible toxic principle serve as a protective resistant barrier against the smudge organism, but in white onions the uncolored outer scales have no such property. This paper is a report upon the results of an investigation which has led to the conclusion that a phenolic acid, known as protocatechuic acid, is one of the substances responsible for the resistant character of colored onion varieties.

EXPERIMENTAL RESULTS

Methods. Quantities of the dry outer scales of white, red, and yellow onions were secured from the bulbs after harvest. From such materials extractions were made by the use of various solvents. The various steps taken in the fractionation of the extracts are described in detail during the course of the paper. Standard color and precipitation tests for the identification of phenolic substances were used. Since these tests are fully discussed by Haas and Hill (1) it seems unnecessary to repeat their description here.

During the steps of the extractions the fractions were tested repeatedly for their toxicity to the spores of *Colletotrichum circinans*. The rupturing of the tips of the germ tubes, characteristic of the crude toxic solutions, already described (6), was relied upon as an indicator as to whether the unknown toxic substance was being preserved during the course of the extraction.

Preliminary steps. Preliminary qualitative tests made with cold-water extracts from dead outer scales of white, yellow, and red onions indicated the presence of soluble phenolic compounds in the solutions from colored scales and their absence from those from white scales. Perkin and Hummel (4) had previously shown the presence of free quercetin, a phenolic compound, in colored scales of onion, but, since this substance is quite insoluble in cold water, it could not be the cause of the positive reaction for phenols nor could it be responsible for the toxicity of such solutions. The latter statement is further substantiated by the fact that crystals of quercetin, prepared from colored onion, when added to a suspension of spores of *C.*

circinans had no effect upon germination and growth. As pointed out in a previous paper (2), the possibilities of a soluble glucoside of quercetin and of a tannin glucoside also were excluded. The next problem, therefore, was to separate, if possible, the toxic compound or compounds from impurities and at the same time retain their original chemical structure and toxic character.

After preliminary tests of the efficacy of ether, 95 per cent alcohol, ethyl acetate, and acetone for the removal of the toxic substance by continuous extraction, the last-named solvent was selected as being the most suitable. Yellow scales were dried at 80° C., finely ground, and continuously extracted with acetone for 14 hours. The extract contained the toxic substance together with quercetin, traces of glucose, fat-like substances, and a reddish brown pigment of an unknown nature. In order to get rid of the quercetin, the acetone was evaporated, and water, in which quercetin is insoluble, was added to the dry residue. The toxic substance and the water-soluble impurities went into solution, which upon filtering, gave the typical qualitative reaction of the ordinary aqueous extract of the scales. When tested against spores of *C. circinans,* it completely prevented germination in dilutions of 1 to 8 and 1 to 12. At 1 to 16 an occasional spore started to germinate but the growing tips ruptured, while the latter reaction was more general at 1 to 20 and very abundant at 1 to 30. No normal germination occurred except at 1 to 30 when an occasional short germ tube was noted. This procedure was repeated several times with similar results.

This crude aqueous solution was next concentrated to a thick sirup under reduced pressure at temperatures below 40° C. The concentrate was treated with a mixture consisting of about 20 times its volume of alcohol and 40 times its volume of ether and allowed to stand for some hours. The reddish brown precipitate was filtered, dried, and brought into solution in water. It gave only a very faint reaction with ferric chloride and, when tested against spores of the smudge organism, it prevented germination at a dilution of 1 to 2 but had no inhibitive effect at 1 to 5. It was obvious that only a trace of the toxic substance was present in the precipitate.

The alcohol-ether solution was evaporated, and a portion of the residue, which was of a light-orange color, was taken up in water. It gave a strong ferric-chloride reaction. When tested with spores of *C. circinans* it entirely prevented germination at dilutions up to 1 to 120. At dilution 1 to 240 and 1 to 480 a large percentage of the spores had ruptured germ tubes and no normal germ tubes were present. At 1 to 960 a small percentage of the spores formed germ tubes but growth was distinctly retarded and an occasional tube ruptured. At 1 to 1920 a high percentage of the spores

germinated and normal growth ensued without any evidence of inhibitive effect.

In another experiment the residue from an acetone extract was dried and then taken up in water and filtered. The aqueous solution was shaken with ethyl acetate until separation was as complete as practicable. The ethyl acetate was evaporated, and part of the almost colorless residue was dissolved in water. It gave a very strong ferric-chloride reaction when tested against spores of the smudge organism. The solution was toxic in dilutions up to 1 to 3300 in which rupturing of the germ tubes was common but no normal germ tubes were noted. At lower dilutions no germination whatsoever occurred. At 1 to 6600 there was a high percentage of normal germ tubes and an occasional ruptured one.

Extracted scales not toxic. After the acetone extraction, samples of the extracted scales were dried and tested for toxicity. Suspensions of spores of *C. circinans* in drops of water were added to suitable amounts of the scales on glass slides, which were then placed in moist chambers and left for 24 hours. Checks with ground unextracted scales were also made. After 24 hours the spores in the drop of water around the extracted scales had all germinated and produced normal germ tubes, whereas rupturing of germ tubes was general among those spores in the solution containing the unextracted scales.

This showed that all of the toxic material was removed and carried into the acetone solvent.

Isolation of and toxicity tests with protocatechuic acid. In the experiments thus far reported it was shown that the toxic principle was completely removed from colored scales by extraction of the latter with acetone and that it could be separated from a large proportion of the nontoxic impurities by the use of neutral solvents at temperatures not exceeding the boiling point of acetone (57° C.). Attempts were next made to obtain the toxic principle in larger quantity. A somewhat modified method of extraction was followed, in which the initial extraction was made in water instead of in acetone. Three bags of yellow-onion scales weighing about five pounds each were steeped overnight in sufficient water to cover them. The colored aqueous extract was treated first with neutral and then with basic lead acetate until no more precipitate was obtained. The latter was filtered off, suspended in water, and decomposed with 2.5 per cent sulphuric acid. The solution was then shaken with ether, the ether solution was separated, and the solvent was evaporated. The residue contained a mixture of isolated crystals and an amorphous pigmented substance, which when dissolved in water gave a strong ferric-chloride test. The solution was toxic up to a dilution of one part of the dried residue in 1900 parts of water, in which a large percentage of the spores showed ruptured germ tubes after 24 hours.

Another lot of scales was then treated in a similar manner and an effort made to obtain the crystals in pure form. The details of their purification and identification as protocatechuic acid (3, 4-dihydroxybenzoic acid, $C_7H_6O_4$) are reported elsewhere (2, 3). When the pure acid was finally obtained it was dissolved in water and tested against spores of *C. circinans* in a number of dilutions. At 1 to 100, 1 to 200, 1 to 400, and 1 to 800 it prevented germination of the spores. At 1 to 1600 a high percentage of the spores germinated but practically all of the germ tubes ruptured. At 1 to 3200 the percentage of normal germ tubes was greater but still many of the germ tubes ruptured. Only at a dilution of 1 to 6400 were satisfactory germination and growth obtained.

In the results thus far reported, yellow-onion scales were used as the source of the toxic substance, protocatechuic acid. Since red varieties of onion are equally resistant to smudge, the procedure was repeated, starting with dry outer scales from bulbs of this color. From these were secured crystals of the acid identical with those of the yellow scales in composition and toxicity. All attempts to isolate the acid from white scales failed.

DISCUSSION

Wide variations in resistance and susceptibility to certain diseases has been commonly noted among varieties, strains, or individuals of many species of plants. In the cultivated species much of economic value has been and is being brought forth in the way of plant improvement through the discovery of resistant strains or through the perfection of new strains by means of selection and hybridization. The study of the nature of these differences in resistance has offered a peculiar challenge to plant scientists not only because of its purely scientific interest but also because of the obvious value of the results of such study as a basis of further plant improvement.

It is by no means implied that a common explanation may be expected for all cases of resistance in plants. Much evidence has already been accumulated to show a variety of reactions between resistant hosts and their would-be parasites. Since much of the literature pertaining to this question has been summarized elsewhere (7), it will not be discussed in detail here. In many of the cases studied one is led to suspect that the fundamental fact underlying resistance may be the presence of a substance or a group of substances in the cells of the resistant host which are toxic to the invading parasite, while in the cells of plants in a susceptible but otherwise quite similar variety these toxins are absent or so limited in quantity as to be ineffective. Such toxic substances, though present, are not usually readily isolated in their natural form, and the difficulties involved in the biochemical studies of these questions quite naturally hinder progress.

In the case of onion resistance herein described the writers were impressed with certain facts which seemed to offer an unusually attractive line of approach to this general problem. In the first place, the toxic substance or substances readily diffused from the dry outer scales into cold water. Secondly, they caused upon the germinating spores of the parasite a peculiarly characteristic effect which might be used as a basis of identifying them if they should be secured in pure form. As already shown, these two advantages greatly facilitated the work. The fact that protocatechuic acid could be extracted through the use of neutral solvents at room temperatures (20° to 30° C.) is a strong indication that it exists as such in the plant. That the toxic substance was practically unaltered during the process is shown by the fact that when the crude extract was tested during successive steps of its purification it continued to give the same chemical reactions and to cause the characteristic rupturing of the germ tubes of *C. circinans*. There seems, therefore, little doubt that protocatechuic acid, which is absent in white onions and present in the scales of colored onions, is one of the principal causes of disease resistance noted in varieties of the latter type.

This should not be interpreted, however, as implying that protocatechuic acid is the sole cause of resistance. As already stated (2), the yield of this substance by the present method is not sufficient to account for all the toxicity of the crude extract. It is reasonable to suppose that some may have been lost during extraction and purification. On the other hand, the possible presence of other closely related compounds which may contribute a share of the resistance is not to be overlooked. These are questions still under investigation.

The close association of this phenolic acid (protocatechuic acid) with the pigment quercetin, one of the pigments of the onion, should be emphasized here. Protocatechuic acid is not a pigment. It is, however, a constituent of various flavone and anthocyan pigments. Quercetin, the 1:3:3-tetrahydroflavonol, is composed of oxalic acid, phloroglucinol, and protocatechuic acid and upon alkaline fusion breaks up into these three components. The chemical stability of quercetin is of such an order that under the conditions in which the protocatechuic acid was isolated the latter could not have arisen by decomposition of the quercetin. In the pigmented onion protocatechuic acid is apparently an accompanying substance of the pigment quercetin. In the three other cases (2) it has been shown that the pigment quercetin is accompanied by the phenolic acid (protocatechuic acid).

With regard to the bearing upon the general problem of disease resistance, these results may have some significance. So far as the writers

are aware, this is the first instance where resistance to or immunity from disease in plants or animals has been definitely shown due to a specific chemical compound produced by the host, although the existence of such toxic substances has often been suspected as the cause of such phenomena. Generalization on the basis of an isolated case is unjustifiable, and it has already been emphasized here and elsewhere that even in this instance the accessibility of the toxic substance at the critical point where invasion of the parasite may occur is quite as important as the presence of the substance. On the other hand, it is not without significance that this specific substance has been found in species of plants widely removed from the onion. Further search may reveal a more general occurrence, since the class of chemical substance to which it belongs is widely distributed in the plant kingdom.

SUMMARY

This paper is a report of a study of the chemical nature of the disease-resistant principle previously noted in colored varieties of onion and not found in white ones.

Preliminary qualitative tests showed the presence of phenolic compounds in toxic water extracts from dry outer colored scales, while none were found in the water extracts from white scales.

One of the toxic compounds was isolated in crystalline form from the crude water extract of dry outer colored scales and identified as the phenolic acid commonly known as protocatechuic acid. This exists in the colored outer scales in the free state, is readily soluble in water, and in dilutions up to about 1–3000 produces the same type of toxic effect upon spores of the smudge organisms as does the crude water extract. It is not present in the white scales. This substance is considered to be one of the compounds responsible for disease resistance in colored onions.

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DRY ROT OF CORN CAUSED BY DIPLODIA MACROSPORA EARLE

A. H. EDDINS

INTRODUCTION

One of the common diseases of corn in Florida is caused by the fungus *Diplodia macrospora* Earle (5). This organism was first reported on old weathered cornstalks at Auburn, Alabama, in the spring of 1896 (4). In 1908 Stevens and Hall (8) found that it caused an ear mold of corn in North Carolina. Since only brief notes constitute the published accounts of the disease and the fungus, the studies herein reported were undertaken to obtain further information concerning the importance and symptoms of the disease, and morphology, taxonomy, physiology, pathogenicity, and survival of the causal organism.

DISTRIBUTION AND IMPORTANCE

Dry rots of corn caused by *D. macrospora, D. zeae* (Schw.) Lév. (1, 3, 7), and *D. frumenti* Ell. and Ev. (6) are well distributed in the different corn-growing localities of Florida. However, they differ from each other in frequency of occurrence and destructiveness.

A microscopic examination of the spores borne in pycnidia on 618 stalks showed that 496 stalks were infected with *D. zeae,* 102 with *D. macrospora,* and 20 with *D. frumenti.* Occasionally stalks were found with pycnidia of two species of Diplodia on them and in a few cases the three species occurred on the same stalk. Furthermore, observations made during the seasons of 1928 and 1929 in Florida show that *D. zeae* ranks first, *D. macrospora* second, and *D. frumenti* third in causing destructive ear rots of corn.

SYMPTOMS

Stevens and Hall's (8) description of the disease caused by *D. macrospora* is brief and inadequate. In Florida, this fungus attacks the ears, husks, ear shanks, stalks, leaves, and roots of corn plants. The symptoms of the disease on these plants are as follows:

Ears, husks, and shank: Badly diseased ears are shrunken and shriveled and tightly clasped by the husks. On such ears the white mycelium of the fungus is visible on the kernels and between the kernel rows (Fig. 1). Usually the inner husks also are covered with the white mold. The kernels are lusterless in appearance and often gray, though seldom black. Pycnidia may occur on the sides and tips of kernels and on the husks. In many cases only one end of an ear is diseased, the butt end being most often involved. The mycelium of the fungus may or may not be visible on the kernels of

ears that are not severely diseased. On some ears the white mold can be seen only on the tips of kernels. On others the disease is detected only when the fungous mycelium grows out of the kernels in the germinator.

The disease on the shank is recognized by the presence of pycnidia on its surface. In some cases the mycelium may be seen growing on the surface of the shank if sufficient moisture has been retained in the crevice formed by the enclosing ear sheath.

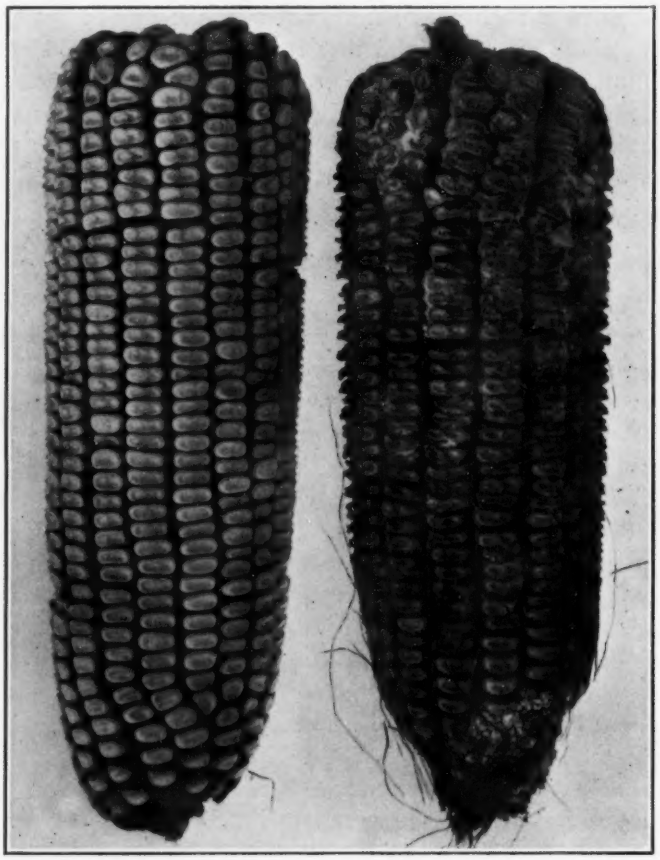

FIG. 1. Ear rotted by *Diplodia macrospora* (right) and a normal ear (left).

Leaves and stalks: Diplodia macrospora attacks the leaf sheaths and occasionally the leaf blades. Infected areas on these parts appear water-soaked to yellowish at first and later become brown, when the tissue is killed by the fungus. The disease may appear on any part of the blade and sheath, although the latter is most often infected at the base. The

lesions on the blade are irregular elongate in shape and may coalesce and form dead spots two inches in length and a half inch in width. The spots usually bear a few scattered pycnidia of the organism (Fig. 2, A).

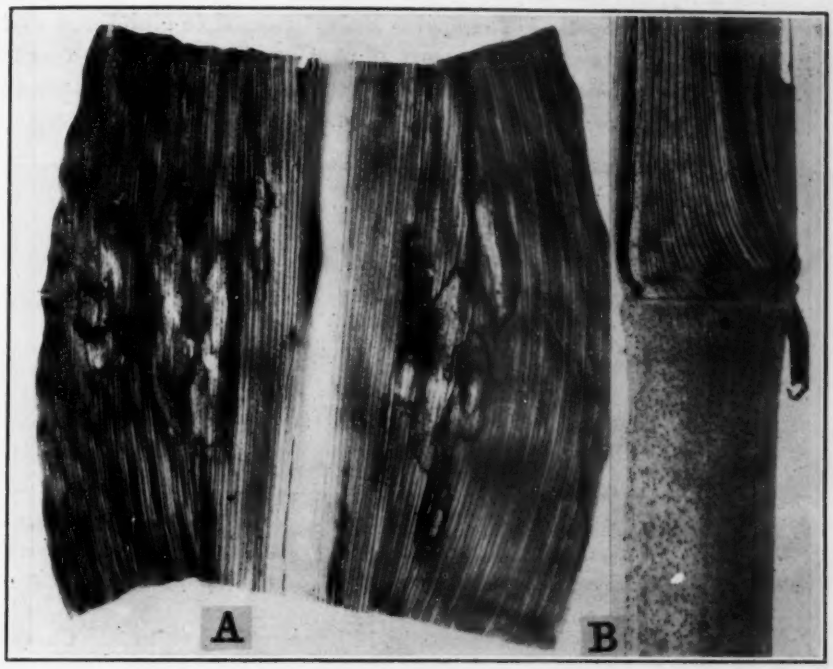

FIG. 2. A. Corn leaf showing pycnidia of *Diplodia macrospora* on diseased areas. B. Old corn stalk showing pycnidia of *D. macrospora* on the internode and node.

The fungus may attack the stalk at any node or internode, but the lower part of the plant is most often involved. The occurrence of pycnidia of the organism on the surface of the stalk at nodes and internodes is shown in figure 2, B. Stalks that are severely rotted at the lower nodes are sometimes blown down by the wind.

Roots: The disease has not been observed on the roots of plants in the field. However, the roots of seedlings grown in inoculated soil in pots in the greenhouse were rotted by the fungus. The invaded roots turned brown, shrank, and died, and the plants were either stunted in growth or killed.

CAUSAL ORGANISM

Morphology: The pycnidia of *D. macrospora* occur scatteringly on the dead parts of the corn plant (4) and are embedded in stromatic masses of mycelium and in host tissue, becoming erumpent at maturity. They are carbonaceous and flask-shape and measure 150–450 μ.

Immature pycnospores are granular and, when mature, are light brown, and frequently contain oil drops. They are borne on short hyaline conidiophores which arise from the inner cell wall tissue of the pycnidium and, at maturity, are discharged, under favorable conditions, through the elongated canal or ostiolum. The spores are cylindrical to club-shape and slightly curved to straight and consist of one, two, three, or four cells (Fig. 3, D), the two-cell type being the most common. They measure 43–95 x 6–13 μ, mostly 60–75 x 8–10 μ and average 67.8 x 9.0 μ.

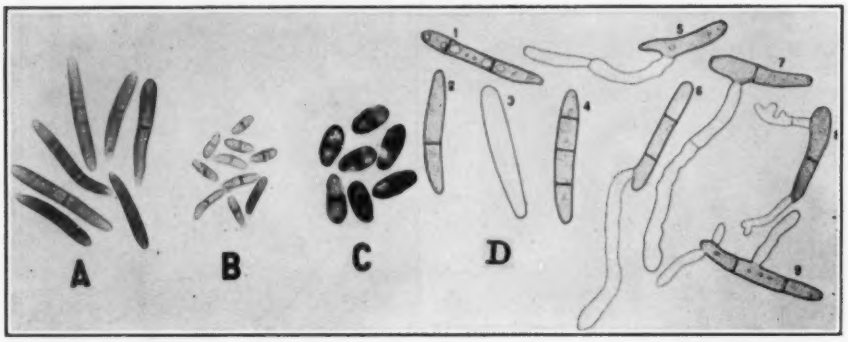

FIG. 3. A, B, C. Photomicrographs of spores. ×200. A. *Diplodia macrospora*. B. *D. zeae*. C. *D. frumenti*. D. Camera-lucida drawings of spores of *D. macrospora*: 1–4, various types of spores; 5–9, various types of spores germinating.

The spores germinate in water within 16 hours at 28° C. to 32° C., and each one of the cells of a spore may form a germ tube. The germ tubes and hyphae are at first hyaline and later become granular, septate, and branched. The growth of colonies of the organism on potato-dextrose agar and malt-extract agar is rapid, since only four days are required for a colony to become 9 cm. in diameter. The mycelium is dense and white.

Taxonomy: Diplodia macrospora and *D. zeae* (3) produce the same type of disease symptoms on the plant. Kernels of ears visibly infected with *D. frumenti* are blackened and often covered with a dark brown to black mold, while kernels infected with *D. zeae* and *D. macrospora* are seldom blackened but have a lusterless appearance and are often dull gray. Pycnidia of *D. frumenti* appear in clumps on the stalk and break out through longitudinal cracks in the epidermis (6), while those of the other two species usually occur singly and rupture the epidermis only at the point of their emergence.

The three species can be distinguished from each other on the basis of certain morphological characters, which are given in table 1 and shown in figure 3, A, B, C. *Diplodia frumenti* differs from the other two species in

TABLE 1.—*Comparison of some of the morphological characters of D. macrospora, D. zeae, and D. frumenti*

Species	Color of mycelium	Shape of pycnospores	Number of cells in pycnospores	Color of mature pycnospores	Dimensions in microns of 200 pycnospores of each species	
					Limits in dimensions	Average Dimensions
D. macrospora	White	Cylindrical to club; slightly curved to straight	1 to 4	Light brown	43–95 x 6–13	67.8 x 9.0
D. zeae	White	Cylindrical to club, rarely elliptical; slightly curved to straight	1 to 3	Light brown	17–33 x 3– 7	23.8 x 5.3
D. frumenti	Brown	Elliptical	1 to 2	Dark brown	19–31 x 11–15	25.3 x 13.3

color of mycelium and in the shape, color, septation, and dimensions of the spores. The mycelium of *D. macrospora* is white, like that of *D. zeae*, and the spores of the two species have the same color and shape. The only outstanding difference between the two species is that the spores of *D. macrospora* are from two to three times as long and about twice as wide as those of *D. zeae*.

Growth on culture media: Diplodia macrospora grew well at room temperature on corn-meal, carrot, oatmeal, lactose, potato-dextrose, and malt-extract agars in petri plates inoculated with uniform bits of mycelium from pure culture. There was little mycelial growth on glycerine agar. At the end of thirty days, pycnidia were formed on all of the above media except lactose agar. The organism also grew well on sterilized corn, wheat, and oat kernels and formed pycnidia in abundance within 68 days from the date of inoculation.

Relation of temperature to spore germination: Spores were germinated in water in drop cultures exposed to temperatures ranging from 5° C. to 39° C. in electrically controlled chambers in which the temperatures did not vary more than plus or minus one degree. Observations made at the end of 24 hours showed that the optimum-temperature range for germination was 25° C. to 32° C., as is shown in figure 4, A. Spores exposed for 6 days at 8° C. germinated 24 per cent, while no germination occurred at 5° C. during the same period, thus showing that the minimum temperature for germination lies between 5° C. and 8° C. The maximum was not ascertained.

Relation of temperature to mycelial growth: A series of plates of potato-dextrose agar were inoculated in the center with uniform bits of fungus mycelium and were incubated in triplicate for 4 days at different temperatures ranging from 5° C. to 39° C. The diameter of the colonies was measured at the end of 2 and 4 days and the average diameter of the three plates at each temperature is shown graphically in figure 4, B. The optimum temperature for growth of *D. macrospora* lies between 25° C. and 32° C. The maximum lies between 35° C. and 39° C., and the minimum between 5° C. and 8° C. It is interesting to note that the cardinal temperatures for the growth of *D. macrospora* closely approached those of *D. zeae*, as determined by Durrell (3).

Relation of hydrogen-ion concentration to mycelial growth: A 3 per cent potato-dextrose agar was used as the medium to determine the effect of hydrogen-ion concentration upon the rate of growth of the fungus. Thirty test-tubes, each containing 15 cc. of the medium, were sterilized and adjusted to different hydrogen-ion concentrations ranging from pH 2.0 to 8.5, by adding the required number of drops of 2N, N/1, and N/3

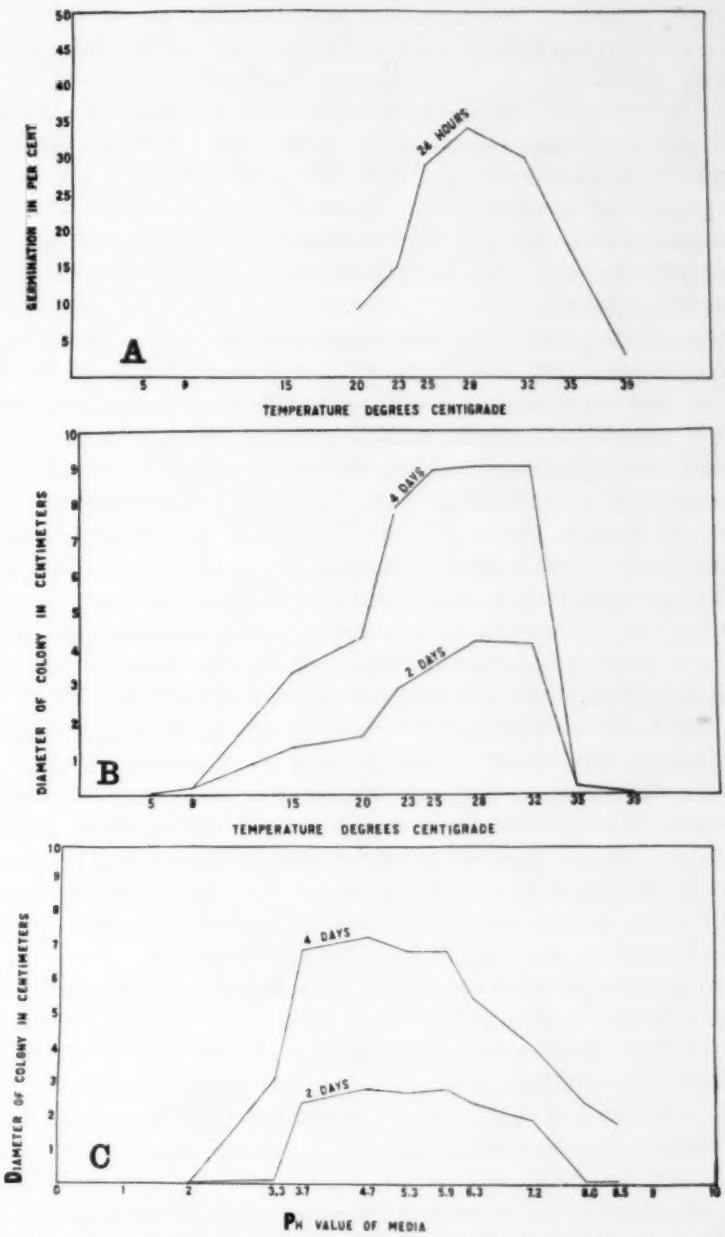

FIG. 4. A. Graph showing relation of temperature to spore germination of *Diplodia macrospora*. B. Graphs showing relation of temperature to mycelial growth of *D. macrospora*. C. Graphs showing relation of pH reaction of media to mycelial growth of *D. macrospora*.

HCl and N/1 NaOH. The amount of acid and alkali required for the different concentrations was determined with the Youden Hydrogen-Ion Concentration Apparatus. Petri plates were prepared in triplicate for each reaction, inoculated in the center with uniform bits of fungus mycelium, and exposed at a constant temperature of 30° C. for 4 days. The average diameter of the colonies of each reaction at the end of 2 and 4 days is shown graphically in figure 4, C.

The results show that the pH reaction most favorable for growth lies between pH 3.7 and 5.9. No growth occurred at pH 2.0 and the organism grew slowly at pH 8.5.

Pathogenicity. Ears: Diplodia macrospora proved to be parasitic on ears of corn artificially inoculated when in the soft-dough stage. In the season of 1928, 44 ears were inoculated by inserting a kernel of corn on which a pure culture of the fungus was growing into a wound made in the husks and pressing it down in contact with the kernels (7). Forty-three of the 44 ears were severely rotted by *D. macrospora*, which formed pycnidia on the outer husks. Forty-eight ears inoculated by the same method in 1929 also were severely rotted by the fungus.

In another test, ears were inoculated by spraying a water suspension of spores on the exposed tips of ears and by hypodermically injecting this inoculum into the husks near the butt end (1, 7). Four of the 19 ears inoculated at the tip were infected and rotted by the fungus, and 7 of the 19 ears into which the spores were injected were also severely rotted. These results indicate that, under natural conditions, *D. macrospora* may enter the ear through exposed tips and through wounds. In nature, ears are most commonly infected at the butt end, and wounds at this point are not essential for infection to occur, for the fungus can grow into the ear from primary infections in the ear shank and in the husks near the butt end. Thus, ears may become infected by *D. macrospora* in the same manner as they are infected by *D. zeae*, as described by Durrell (3).

Seedling roots: Healthy corn seedlings with roots an inch to two inches long were set out in sterilized white lake sand and in sand sterilized and inoculated with a pure culture of *D. macrospora*. At the end of two weeks the roots of the seedlings in inoculated sand were severely rotted by the fungus. The infected roots were shrunken and light brown and the tops of the plants were either wilted or dead. Plants grown in noninoculated sand had healthy roots and a normal top growth. In this experiment the amount of inoculum was greatly in excess of what normally occurs in the field, and the test indicates the parasitic capabilities of the fungus and not its actual pathogenicity for seedling roots in the field (2, 3).

Overwintering: Diplodia macrospora survives the winter in Florida in old plant débris. Spores collected from old stalks left in the field until May

germinated readily and produced ear infection. The organism also lives over as dormant mycelium in the kernels. Its longevity beyond one year has not been determined, but, like *D. zeae* (1, 3), it is probable that *D. macrospora* is capable of living several years on old plant refuse and in the soil.

SUMMARY

Diplodia macrospora causes a dry rot of the ears, husks, ear shanks, stalks, leaves, and seedling roots of corn in Florida. This disease can be distinguished from dry rot caused by *D. frumenti* on the basis of symptoms, but the symptoms of dry rot caused by *D. zeae* are similar to those caused by *D. macrospora*, and the diseases can be distinguished only by comparing the size of the spores of the two organisms from diseased parts of the corn plant.

The chief morphological difference between *D. macrospora* and *D. zeae* lies in the size of the spores. *Diplodia frumenti* differs from these two species in color of mycelium and in color, shape, size, and septation of the spores.

Diplodia macrospora grows well and forms pycnidia on standard culture media.

The optimum temperature range for spore germination and mycelial growth of the organism is 25° C. to 32° C., and the minimum lies between 5° C. and 8° C. Spores germinate at 39° C., but there is no mycelial growth at this temperature.

Diplodia macrospora grows best on potato-dextrose agar at pH 3.7 to 5.9. The minimum pH reaction lies between 2.0 and 3.3 and the maximum lies above pH 8.5.

The organism enters the ears through exposed tips and wounds and by growing through the shanks. It hibernates as dormant mycelium in the seed and in old plant débris and in the soil.

FLORIDA AGRICULTURAL EXPERIMENT STATION,
GAINESVILLE, FLORIDA

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PHYTOPATHOLOGICAL NOTES

A new method of sterilizing wood blocks to be used for the culture of wood-inhabiting fungi. The surfaces of wood blocks are readily sterilized by exposure to the fumes of glacial acetic acid. Following is the recommended procedure: Cut the wood into blocks of the size desired for cultures and place them in a glass dish containing an open vessel filled with glacial acetic acid; cover the dish; and leave the wood exposed to the acid fumes for six hours. At the end of three hours turn the blocks in order that all points on the surface of the wood may be reached by the acid. At the end of six hours the surface of the wood will be sterilized.

A culture dish 10 inches in diameter, provided with a cover and fitted with stands on which to rest the wood blocks, makes a suitable container for the sterilization of 4 blocks, 1 inch x 1 inch x 3 inches in size. Satisfactory stands to hold the blocks may be made by bending the ends of glass rods at right angles to the rods and fitting them into corks, which will act as supports to maintain the rods in a horizontal position in the sterilization vessel. An open dish containing the acid may be placed below such stands.

In the course of sterilization the surface of the wood will have absorbed some of the acid fumes; and, before the blocks are removed to the vessel in which they are to be inoculated, it is necessary to free them of the disinfectant. The fumes diffuse readily into the air. Transfer the blocks, therefore, to a dry, sterilized vessel into the air of which the acid may pass; if the presence of acid is still discernible after a few hours, transfer the blocks to a second sterilized vessel. When all the perceptible acid has disappeared, pass the blocks through several changes of sterilized distilled water to insure the removal of every trace of acid. This will, in addition, condition the wood to a moisture content suitable for fungous growth. It is well to pass the blocks somewhat rapidly through the first changes of water, leaving them not more than an hour in the first, in order that no trace of the acid may soak into the interior of the wood.

The method of sterilization here outlined is superior to sterilization by heat, since subjection of wood to heat for a period of time sufficient to insure the destruction of fungus spores or mycelium adhering to the surface changes to some extent the chemical composition of the wood and, therefore, alters the food supply of any fungus with which it may be inoculated. It must be remembered, however, that the acid sterilizes the surface of the wood only and that, therefore, thoroughly sound wood must be selected at the outset. It is well to run control cultures containing treated but noninoculated blocks, in order to ascertain whether or not any active fungus is present in the wood before inoculation.

All the fungi that I have attempted to grow on culture blocks prepared as here described have developed well. These are three in number: *Trametes pini* Fr. inoculated into blocks of jack pine, *Pinus Banksiana* Lamb.; *Torula ligniperda* (Willk.) Sacc. on blocks of paper birch, *Betula alba*, var. *papyrifera* (Marsh.) Spach.; and *Fomes igniarius* Fr. also on paper birch, *Betula alba*, var. *papyrifera*.

Trametes pini reduced sound jack pine to an advanced white-pocket stage of red rot and produced sporulating fruit surfaces on the blocks in a period of eight months. *Torula ligniperda* has caused a distinct discoloration of the birch blocks to a depth of 3/16 inch in the course of three months and has doubtless penetrated much farther into the wood. This fungus is sporulating freely in the interior of the blocks. *Fomes igniarius* is spreading rapidly over the surface of the wood, but the inoculations are recent, and none of the blocks have yet been removed from the culture flasks.—CLARA W. FRITZ, Timber Pathologist, Forest Products Laboratories of Canada, Ottawa, Canada.

Additional data on the distribution of two species of Sphaceloma. It now seems certain that the distribution of the Sphaceloma on avocado, the cause of avocado scab, includes the country of Mexico. This statement is based upon the writer's identification of the fungus on avocado fruits recently recovered by Inspectors of the United States Department of Agriculture Plant Quarantine and Control Administration from the baggage of passengers at El Paso, Texas, entering the United States from Mexico. The organism had formerly been reported from Peru and Cuba, as well as from Florida. Its possible occurrence in Mexico, where the avocado is indigenous, would seem almost unquestionable but an earlier record has not been found.

Reports of a Sphaceloma on apple and pear in Europe have been received only from Russia and Switzerland. Its identification on apple fruits taken during the past six months by Inspectors of the Plant Quarantine Administration from the baggage of passengers coming to this country from both Italy and Ireland shows that this organism occurs also in these two countries; that is, presuming that the apples in each instance were grown in the country whence they were transported. The finding of a Sphaceloma on apple, apparently from Ireland, together with other available data to be reported later, suggests that this organism may cause the British "spot-disease" of the apple, the cause of which has not been definitely determined. The fungus is not known to occur in the United States. —ANNA E. JENKINS, Bureau of Plant Industry, Washington, D. C.

Notice of Summer Meeting. The Southern Division of the American Phytopathological Society will hold its annual Summer Meeting June 11–16, 1930. The arrangements for the field tour are under the direction of Dr. L. E. Miles, Chairman, and L. M. Fenner, Secretary. The group will assemble at the Walthall Hotel in Jackson, Mississippi, during the evening of June 11. On June 12, an early departure will be made southward to the truck-crop areas around Crystal Springs and Hazlehurst. This is the center of the fresh-tomato district. Field operations, grading, and packing may be observed. Tomato shipments will be at their height. In the field, observations will be made on the overwintering of bacterial canker of tomato and other tomato diseases. Diseases of beans, carrots, cotton, and sweet potatoes will be noted here and in the coastal area. Search will be made for the newly discovered phony disease of the peach. Departing from the famous health resort at Browns Wells on June 13, visits to pecan groves and nurseries will be made and the work of the South Mississippi Experiment Station at Poplarville will be noted. Citrus, figs, grapes, peaches, sugar cane, and gladiolus will be of interest here. From Hattiesburg, on June 14, the tour will include diseases of citrus, pecans, and sugar cane, arriving in Biloxi late that afternoon. Visits to truck-crop areas, nurseries, and the pecan station will be made on June 16.

For members interested in the collecting of fungi, this tour should afford an opportunity for gathering unusual specimens. The winter and spring seasons have been cool and rainy over much of the State and the conditions may favor a considerable number of plant diseases.

The State Plant Board of Mississippi and the Agricultural Experiment Station have tendered their services in making the tour available to visitors who may come by train. All members, visiting scientists, and agricultural workers interested in plant diseases and their control are extended a cordial invitation to meet with us. Requests for reservations should be addressed to the Committee at A. & M. College, Mississippi.

REPORT OF THE TWENTY-FIRST ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

THE DES MOINES MEETING

The American Phytopathological Society held its twenty-first annual meeting from Saturday through Tuesday with an attendance of about 150. Saturday and Tuesday meetings were held at the Grant Club, with headquarters at the Chamberlain Hotel. Monday sessions were conducted at Iowa State College, at Ames.

The program consisted of ninety-three papers delivered before the Society's sections and five delivered at two joint sessions, one with Section G of the American Association and the other with the Society of American Bacteriologists. The contributions may be classified as follows: cereal diseases, twenty-five; vegetable diseases, thirty-two; fruit diseases, thirteen; miscellaneous diseases, twelve; diseases of ornamentals, nine. There were two invitation papers, one by Christine Buisman, on the Dutch elm disease, and the other by R. P. White, on the future of the pathology of ornamentals.

The annual banquet on Saturday evening, 163 persons present, will long be remembered because of the clever program of original songs, impersonations, etc., rendered by members from Iowa, Minnesota, and Wisconsin.

On Sunday evening was held the second annual meeting with business men and farmers, the discussion this year being devoted to the timely subject: "What Present Trends in Agriculture Demand of Plant Pathology." Thomas Roberts (General Milling Company) spoke on the great west and wheat; the nation's greatest crop, corn, was discussed by H. A. Wallace (Wallace Publishing Company); the sugar-beet industry was represented by W. H. Baird (American Beet Sugar Company); and a paper on conserving the intensive crops prepared by C. G. Woodbury (National Canners Association) was read.

The Monday sessions were held at Iowa State College, at Ames, where there was an elaborate exhibit of experimental work. Displays of virus diseases, crown-gall investigations, and seed-corn treatments were noteworthy. There were three simultaneous sessions Monday morning and a joint session in the afternoon with the Society of American Bacteriologists, before which papers were given on bacteriophage and plant and animal viruses.

A sum of money equivalent to that taken in for the Endowment Fund Luncheon, which was a feature of the day, was contributed to the fund by the Iowa State College group. Following the luncheon, members present as guests contributed generously.

The extension pathologists held a round-table discussion on Tuesday with R. E. Vaughan, of Wisconsin, as chairman. The importance of conducting disease-control projects in close cooperation with other extension work was emphasized.

OFFICERS AND REPRESENTATIVES

The following officers were chosen:

President, H. S. Fawcett, Citrus Experiment Station, Riverside, Calif.

Vice-President, Max W. Gardner, Indiana Agricultural Experiment Station, La Fayette, Ind.

Councilors (two years), H. P. Barss, Oregon Agricultural Experiment Station, Corvallis, Ore.; W. D. Valleau, Agricultural Experiment Station, Lexington, Ky. (1 year to complete term of Max W. Gardner.)

Associate Editors (three years), Ruth F. Allen, University of California, Berkeley, Calif.; Mary K. Bryan, U. S. Department of Agriculture, Washington, D. C.; L. R. Hesler, University of Tennessee, Knoxville, Tenn.; Wm. H. Weston, Jr., Harvard University, Cambridge, Mass.

Business Manager (one year), F. C. Meier, U. S. Bureau of Plant Industry, Washington, D. C.

Advertising Manager (one year), James F. Adams, Agricultural Experiment Station, Newark, Del.

Representatives on the Council of the American Association for the Advancement of Science (one year), D. Reddick, Cornell University, Ithaca, N. Y.; C. W. Edgerton, Louisiana Agricultural Experiment Station, Baton Rouge, La.

Members of the Board of Governors of the Crop Protection Institute (three years), L. M. Massey to replace H. W. Anderson.

The following temporary committees were appointed to serve throughout the meetings:

Auditing Committee, R. E. Vaughan and J. B. Kendrick.

Committee on Elections, L. M. Fenner and Reiner Bonde.

Committee on Resolutions, H. W. Anderson, R. P. White, and J. G. Leach.

De Bary Memorial Program Committee, Mel T. Cook, F. M. Blodgett, L. E. Melchers.

REPORT OF THE SECRETARY-TREASURER, 1929

The Society started the year 1929 with 794 members. During the year 4 past members have been reinstated and 29 have been lost. Of the 29, 15 have been suspended for nonpayment of dues, 8 have resigned, and 4 have died, 2 of those elected at the New York meeting not having paid their dues. This makes a net loss of 25 and a total membership of 769 at the close of 1929.

There are now 84 life members paid in full—54 paying currently and 631 regular annual members. I have at this meeting applications for 59 and if these are elected it will bring our total membership up to 828.

The State of Minnesota leads in securing new members for 1929 with six applications, Iowa, New York, and Wisconsin tying with five each; Indiana, Washington, and Canada, three each; Illinois, District of Columbia, Hawaii, and Michigan, each two; and the remainder scattered through nine States, and the following foreign countries: England, Greece, India, and Japan.

Our estimate of a working balance of $899.74 for 1930 is ample to take care of the probable needs of the Society.

STATEMENT OF ACCOUNTS FOR 1929, AS OF DECEMBER 15, 1929

Receipts:

Balance from 1928			$2,361.61
Annual dues: 1927	$ 4.00		
1928	24.25		
1929	1,628.20		
1930	2,125.40		3,781.85
Excess dues			.50
Interest on checking account			45.42
Sales received with dues			4.11
Donation to Lyman Memorial Fund received with dues			13.00
Total receipts			$6,206.49

Expenditures: (As per vouchers attached)

Member subscriptions transferred to PHYTOPATHOLOGY (1929)	$2,178.00	
" " " " " (1930)	500.00	
Secretarial work	288.38	
Postage stamps and stamped envelopes	68.45	
Stamped printed envelopes	68.22	
Expenses of Secretary-Treasurer at New York meeting	66.01	
Printing (abstracts, preliminary announcements, ballots, nomination ballots, final programs, tickets, letterheads)	208.71	
Incidental expenses (account books, buttons)	11.70	
Donations to Lyman Memorial Fund to Savings Account	25.00	
Supplies for and mimeographing Publicity abstracts	32.10	
Sales transferred to PHYTOPATHOLOGY	10.44	
Checks returned by bank	46.00	
Bank charges for collection of checks	1.20	
Balance as shown by bank statement attached	2,702.28	
		$6,206.49

SUPPLEMENTARY STATEMENT

Balance as above stated			$2,702.28
Amount of above receipts due PHYTOPATHOLOGY:			
For member subscriptions, 1928	$ 3.00		
1929	63.00		
1930	951.00		
For sales received with dues	.54	$1,017.54	
Amount due Sinking Fund:			
For 1925, 1927, 1928	306.00		
For 1929	522.00		
For 1930	378.00		
		1,206.00	
			2,223.54
Available working balance for 1930 expenses			$ 478.74
Balance from 1929 as per attached statement		$ 478.74	
Estimated income from annual regular members for 1930		372.00	
Estimated interest on December checking account		4.00	
Estimated interest on 1930 checking account		45.00	
			$ 899.74

During my first year as Secretary-Treasurer I have received invaluable assistance from our President, Dr. R. J. Haskell, who, in 1928, at the close of six years' active service, requested relief from this office. It was also my good fortune to have the assistance of Miss Mary G. Van Meter. Her knowledge of the work and her keen interest in the welfare of the Society, combined with a willingness to devote practically all of her spare time to PHYTOPATHOLOGY, contributed much to our year's program.

Respectfully submitted,

F. C. MEIER, *Secretary-Treasurer.*

REPORT OF THE BUSINESS MANAGER OF PHYTOPATHOLOGY FOR 1929

STATEMENT OF ACCOUNTS FOR 1929, AS OF DECEMBER 15, 1929

Receipts:

Balance from 1928			$ 636.54
Subscriptions ($795.51 for 1930)			3,079.34
Sales, PHYTOPATHOLOGY		$ 803.09	
Phytopathological Classics		7.37	
			810.46
Advertising: 1927		23.00	
1928		47.15	
1929		880.63	
			950.78
Interest on Sinking Fund			352.50
Member subscriptions for 1929			2,178.00
Member subscriptions for 1930 (in part)			500.00
Donation to Lyman Endowment Fund			25.00
Donation from National Academy of Sciences			500.00
State of West Virginia, share in cost of Leonian article			425.50
Tropical Plant Research Foundation for colored plate			445.95
Member dues received with subscriptions			5.00
			$9,909.07

Expenditures:

Manufacturing PHYTOPATHOLOGY:			
Vol. XVIII, No. 11	$ 434.24		
Vol. XVIII, No. 12	470.15		
Vol. XVIII, Index	184.43		
		$1,088.82	
Vol. XIX, No. 1	654.06		
Vol. XIX, No. 2	438.75		
Vol. XIX, No. 3	787.52		
Vol. XIX, No. 4	962.39		
Vol. XIX, No. 5	719.03		
Vol. XIX, No. 6	485.08		
Vol. XIX, No. 7	459.63		
Vol. XIX, No. 8	384.78		
Vol. XIX, No. 9	1,027.37		
Vol. XIX, No. 10	633.34		
Vol. XIX, No. 11	430.25		
Vol. XIX, Cuts	913.45		
		7,896.55	
			8,985.37
Expenses of Editor in Chief			113.50
Postage of Editor in Chief			102.48
Secretarial work			89.25
Insurance on stock of back volumes at Lancaster, Pa.			18.00
Postage in mailing back volumes			14.84
Expenses of Advertising Manager			33.24
Donation Lyman Fund transferred to Savings Account			50.00
Duplicate subscriptions refunded			15.25
Balance as shown by bank statement attached			487.14
			$9,909.07

Last year our cash balance in the PHYTOPATHOLOGY account was $636.54, this year it is $487.14. We have paid for eleven numbers of the 1929 Journal but in doing so we have expended 1930 receipts from subscriptions to the amount of $795.50 and we have transferred $500 of the member subscriptions for 1930 from the Society account to help meet this cost. We still have the December number and the Index to pay for and they will probably cost $800, also bills for the commission allowed the Advertising Manager and for stenographic work to the amount of $133.80, making approximately $933.80 due for 1929 expenses and this amount must be paid from 1930 receipts.

Assistance in the publication of PHYTOPATHOLOGY was received this year in the form of a $500.00 grant from the National Academy of Sciences Fund for Publication of the Results of Research.

SINKING FUND

The Sinking Fund composed of six dollars for each sustaining life-membership is now $6,456.00 of which $6,250.00 is invested in first-mortgage notes. The remaining $206 is in the Society's checking account and will be invested as soon as the life-membership dues for 1930 have been received.

ENDOWMENT FUND

The endowment fund established and named for Doctor George Richard Lyman now totals nearly $1,500[1] in cash donations and pledges. Of this amount $828.44 is placed in a savings account with the McLachlen Banking Corporation. There have been cash contributions ranging from $100 to $1.00. Pledges have been received in amounts from $10.00 per annum for 10 years to $1.00 per annum for 5 years.

STATUS OF SUBSCRIBERS

Our edition of PHYTOPATHOLOGY is 1,625 of which 1,267 copies are mailed to members and subscribers. The number of subscribers in good standing at the close of the year is 498, of which 172 are domestic and 326 are foreign. A glance at the record of subscribers for the past ten years shows a growth of 222.

Respectfully submitted,

F. C. MEIER, *Business Manager.*

REPORT OF THE EDITOR IN CHIEF

During the current year the editorial staff of PHYTOPATHOLOGY has conscientiously striven to maintain the high standard of excellence to which our journal has been brought through the labor and devotion of others who have served as its editors. Much credit is due Dr. E. C. Stakman and his associate editors for assistance rendered the editor in chief and his staff in editing the manuscripts and attending to editorial responsibilities attendant upon the publication of the January, February, and March numbers. Grateful acknowledgment also is made on behalf of the helpful criticism and editorial and other valuable assistance rendered by different members of the present editorial staff and by J. Marion Shull, Frances W. Todd, and others.

The 19th volume of PHYTOPATHOLOGY comprises 1,147 pages of printed matter and illustrations classified as follows: Eighty-eight articles, 19 phytopathological notes, 2 reports, 2 book reviews, 38 plates, and 199 text figures. From January 1, 1929, to December 20, 1929, approximately 130 manuscripts were submitted. Of this number, 31 were returned to the authors for revision, 6 were rejected, and 3 were withdrawn by their authors. Volume 19 contains a total of 125 phytopathological abstracts and 15

[1] Two hundred nineteen dollars was received at the Endowment Fund Luncheon at Ames, Iowa, on December 29, 1929. This sum does not appear in the above statement.

abstracts by title only. Of the several manuscripts received during the year 1929, 22 articles, 4 phytopathological notes, 2 book reviews, and 98 abstracts are now in press.

During the past year an effort has been made and, thanks to the helpful cooperation of The Science Press Printing Company, some success has been realized in advancing the date of delivery of our journal to its subscribers. Before another year passes, it is hoped each month's issue will be mailed on the first of the month.

Certain of our membership have expressed the thought that we should formulate and adopt a more definite editorial policy with reference to character and length of articles accepted for publication in PHYTOPATHOLOGY, publication of notes, announcements, book reviews, interim reports, quarantine regulations, etc. Accordingly, a questionnaire was prepared and sent out to a limited number of members, more especially to those who have served or are serving the Society in an editorial capacity. These questionnaires have been returned and from them an attempt will be made to formulate a policy with reference to all points covered in the list of questions.

It is the aim of the editorial staff to cooperate to the utmost in the improvement of the scientific excellence and wide usefulness of our journal. Therefore, no pains will be spared in our effort to obtain manuscripts of exceptional quality both as to subject matter and excellence of exposition. Greater care should be exercised by our contributors in the selection of adequate illustrations of such excellence as to guarantee the best possible reproduction. Contributors should also devote more attention to the clarity of presentation of tabular data and to terseness in statement of scientific facts. Much editorial labor has been expended during the past year and in past years in an effort to publish within the limits of our budget. This has necessitated not a little pruning out of extraneous matter and exclusion of tabular material that could be and has been more advantageously incorporated in the text, proper. Again, we would call attention to the fact that authors of papers can profit through reference to recent numbers of PHYTOPATHOLOGY from which they may learn what is required in the preparation of tables, graphs, and illustrations. Attention to such details and to a more careful preparation of the text will go a long way toward insuring prompt publication of manuscripts.

H. B. HUMPHREY, *Editor.*

REPORT OF THE ADVERTISING MANAGER

In the twelve issues of PHYTOPATHOLOGY published during the year 1929, there appeared a total of 113 advertisements distributed as follows: 38 one-page, 52 one-half-page, 20 one-fourth-page, and 3 one-eighth-page advertisements. The total advertising was equivalent to 69⅝ full pages, or an increase over last year of six and two-thirds pages.

Soliciting advertising is a continuous responsibility each month of the year in order to maintain our small total of business. Renewal of contracts secured for 1930 at this time totals only 36 pages, which further indicates the necessity for continued soliciting and the need of cooperation on the part of members to assist in this work if we expect to maintain a reasonable advertising business.

It is suggested that members write the Advertising Manager of any favorable prospects and whenever in touch with commercial representatives to mention the opportunity PHYTOPATHOLOGY offers as a practical medium for advertising their equipment and materials directly to the members with whom they wish to do business.

J. F. ADAMS, *Advertising Manager.*

COMMITTEE ON INVESTIGATION OF FOREIGN PESTS AND PLANT DISEASES

Your Committee has devoted its time during the past year as follows:

1. To the preparation of a list of important plant diseases based upon an early list prepared by J. A. Stevenson.

2. To conferences between members of the Committee and Secretary A. M. Hyde, Dr. A. F. Woods, Drs. W. A. Taylor and K. F. Kellerman, and other influential leaders in Washington.

3. To correspondence between chairmen of the two coordinate committees whereby it was agreed to present a joint resolution together with substantiating data to Secretary Hyde requesting that an appropriation for this purpose be included in the budget for 1931.

4. To redrafting the resolution adopted by this Society at its last session so that it forms a joint resolution from the Association of Economic Entomologists and the American Phytopathological Society.

5. To the presentation of this joint resolution, together with supporting data, through letter of transmittal to Secretary Hyde signed by members of both committees.

6. To following up the progress of the resolution. At the last report the matter was being considered by the Budget Committee.

C. R. ORTON, *Chairman*,
W. A. MCCUBBIN,
F. D. FROMME.

COMMITTEE ON QUARANTINE AND REGULATORY WORK

This Committee, consisting of W. A. McCubbin, Chairman, J. S. Boyce, J. F. Adams, H. T. Güssow, and M. W. Gardner, submitted the following report, read by Doctor Gardner.

At the present time there appears to be no great demand or need for regulating importations of pathogenic cultures from foreign countries.

The unsatisfactory condition of quarantine aims and policies is noted.

Unification of policies, standards, and practices in nursery inspection seems desirable.

The following resolution is proposed:

Whereas: The American Phytopathological Society cordially endorses the policy of the United States Department of Agriculture in reference to competent and impartial investigation of all outbreaks of foreign plant diseases and insect pests in this country in order that effective and reasonable control measures may be adopted, be it

Resolved: That this Society desires to express its approval of the action taken by Secretary Hyde, of the Department of Agriculture, in appointing advisory groups of well-qualified scientists from various States and institutions to survey and report on the Mediterranean fruit-fly situation in Florida both as to the need and the adequacy of the control measures adopted, including research, eradication, and quarantine.

W. A. MCCUBBIN, *Chairman*.

COMMITTEE ON COOPERATION WITH BIOLOGICAL ABSTRACTS

Your Committee on Biological Abstracts consisting of J. I. Lauritzen, Chairman, L. O. Kunkel, G. W. Keitt, S. M. Zeller, and H. T. Güssow, held no meeting during the year and so can give you only a brief summary of the progress made by Biological Abstracts as reported by Dr. J. R. Schramm.[1]

During the year some 36,000 abstracts were published and 45,000 were sent to press. Beginning with January, 1930, regular monthly publication will be established.

[1] Read by Dr. L. O. Kunkel.

Each number will contain about 3,000 abstracts. It is hoped that the index for Volume 1 can be published sometime next spring.

One of the most important achievements of the past year was the establishment of a branch office in the Library of the U. S. Department of Agriculture. This library has made available $5,000 a year for salaries and $5,000 a year for serials desired both by Biological Abstracts and the U. S. Department of Agriculture. The number of current serials to which the staff of Biological Abstracts has access has been brought to about 5,500. Twenty-five thousand are available at the Academy of Natural Sciences in Philadelphia, 1,200 are at the College of Physicians in Philadelphia, 1,200 are at the central office of Biological Abstracts, and 600 are in the Library of the Department of Agriculture. There are at present over 3,000 collaborators. Dr. Schramm pleads for our continued support. The Committee heartily recommended that all possible support be given to Biological Abstracts during the coming years.

J. I. LAURITZEN, *Chairman.*

COMMITTEE ON EDITING PHYTOPATHOLOGICAL ABSTRACTS

On the basis of the acceptance by the Society of the report made by the Committee on Editing Phytopathological Abstracts December 31, 1928, and published in PHYTOPATHOLOGY, Vol. 19, pp. 520–521, 1929, the Committee has this year applied the following rules:

1. November 15 is the closing date for receipt of manuscripts for phytopathological abstracts for the annual meeting and this is interpreted strictly to mean that the abstracts must be in the hands of the Committee on or before that date.

2. Late receipt of manuscripts and length in excess of 200 words will act automatically to disqualify.

3. Manuscripts presenting material which, in substance, has already been published will not be accepted.

4. The Society has previously ruled that not more than two abstracts under the sole or senior authorship of one person shall be accepted.

It has been necessary this year to reject certain manuscripts because of failure to observe one or another of these rules.

The vexing question of the proper disposition of progress reports, which are in effect only a compilation of a greater or smaller portion of the routine observations, spraying tests, and miscellaneous experimentation performed during the year, still remains. This Committee recognizes that sometimes more can be made of such papers by their actual presentation than is apparent from the preliminary abstract and that they sometimes evoke discussions mutually beneficial to author and audience. We recognize that the presentation of papers of this character is sometimes employed as a means to place one's name on the program and that their acceptance may be an important factor in determining attendance at the meetings. It is not the place or purpose of this Committee to attempt to legislate with respect to the papers which appear on the program, but we hold that a considerable proportion of this sort of material is not scientific literature in a proper sense and should not be published as if it were. Although the Committee is authorized to reject manuscripts which contain no new contribution to knowledge, experience shows that it is very difficult to secure general agreement among the Committee that any manuscript is so deficient. The practice has been to let nothing less than the unanimous judgment of the Committee determine the rejection of a manuscript. As a result we continue to publish abstracts in which no substantially new result, process, or thought is discernible, and the present year is no exception. This situation is discreditable to the high scientific aims of the Society.

We therefore propose the adoption of another rule supplementary to the four rules above stated, as follows:

5. The Committee may at its discretion order printed by title only such manuscripts as do not of themselves give evidence of a new contribution to scientific knowledge.

These five rules will govern the Committee's action with respect to the manuscripts submitted in 1930 and thereafter. It is proposed to publish these rules in a number of PHYTOPATHOLOGY issued prior to October 15 each year, and a synopsis of them in the preliminary notice of the meetings.

FREEMAN WEISS, *Chairman*,
J. W. ROBERTS,
ANNIE R. GRAVATT,
CHARLES DRECHSLER.

COMMITTEE ON PHYTOPATHOLOGICAL CLASSICS

With respect to Phytopathological Classics I can only report that due to the financial stringency in the treasury of PHYTOPATHOLOGY, I have made no attempt the past year to present manuscripts for publication in this series. I can, however, report some progress. Doctor Humphrey tells me that he has the manuscript of the translation of Tillet's paper on cereal smuts on which he has been working for some time practically completed. This can be gotten ready, I take it, for publication within a short time after I am advised that there is money available for printing it. I shall be glad to be advised by the Council as to the prospects of having funds for publishing new numbers of the Classics. As soon as money is again available, this series should be pushed with vigor.

H. H. WHETZEL, *Chairman*.

COMMITTEE ON PRESS

During the year stories were released to the *West Virginia Agriculturalist* and to the alumni magazines of Dartmouth College and Harvard University on the late Dr. G. R. Lyman and the George Richard Lyman Endowment Fund for Phytopathological Publications. The report of the Des Moines meetings, published in *Science*, was released by the Press Service.

The most important phase of the work of the year, and that for which the Press Committee was established, was the preparation of paper-by-paper releases of the Des Moines meetings. Each paper on the program, in so far as the Secretary received abstracts, was rewritten in popular language, and, following the final arrangement of the program, session stories were prepared, each with its proper release date, and mimeographed. Copies of the several stories were mailed to over two hundred newspapers, press associations, farm journals, and feature writers.

Following the meetings at Des Moines, a story of the new officers of the Society, together with photographs in so far as they were available, was released to the Associated Press.

W. A. WHITNEY, *Chairman*.

COMMITTEE ON INTERNATIONAL RELATIONS

Your Committee, appointed to inquire into the desirability of seeking to develop an international organization for the furtherance of our science and the promotion of international cooperation and good will, reports as follows:

1. It has been determined by consultation with a representative gathering of our membership that the time seems opportune for the formation of an international organization.

2. It is recommended that the President appoint a committee (the number to be left to his discretion) to begin at once preliminary negotiations looking to a conference of interested persons, the conference to be held at Cambridge, England, at the time of the International Botanical Congress, in August, 1930.

3. A plan of organization, approved in principle by an informal conference of the Society in session at Des Moines on December 29, 1929, is presented for the information of the proposed new committee.

D. REDDICK, *Chairman*,
H. S. JACKSON,
J. C. WALKER,
H. S. FAWCETT,
G. H. COONS.

COMMITTEE ON NECROLOGY

The decease of four members is reported: Franklin Sumner Earle, January 31, 1929; Charles W. de Rekowski, April 16, 1929; Dr. Leigh H. Pennington, April 24, 1929, and Dr. W. H. Wright, May 3, 1929.

On account of their achievement and personal qualities, these members had won the professional respect and personal friendship of their colleagues. The American Phytopathological Society records its sense of loss in the death of these members. The formal report will be found at the end of this record.

A. G. JOHNSON, *Chairman*,
G. P. CLINTON,
M. B. WAITE.

REPORTS OF OTHER COMMITTEES AND REPRESENTATIVES

Committee on American Type Culture Collection. I submit herein a brief report for the year 1929 of the fungus section of the American Type Culture Collection maintained in the Office of Mycology and Disease Survey, Bureau of Plant Industry.

No. of transfers sent to Dr. Weaver during 1929	199
No. of cultures in collection as report of Dec. 23, 1928	457
No. of cultures in collection Dec. 31, 1929:	
Aspergillus	46
Penicillium	36
Phycomycetes	66
Pythium and Phytophthora	34
Miscellaneous	319
Total available for distribution	501

There are also several dozen recently acquired cultures not yet placed in the collection for distribution.

In June, 1929, a supplementary list of 113 cultures of fungi was sent to Dr. Weaver's office. Since that supplement was compiled about 25 cultures have been placed in the collection.

During the year a culture cabinet large enough to hold 1,200 cultures has been constructed to facilitate handling of the cultures. A minimum of trouble from loss or contamination was experienced during the year.

C. L. SHEAR, Representing Phytopathological Society.

American Association for the Advancement of Science. A brief, informal report of the representatives on the *Council of the American Association for the Advancement of Science* was presented by D. Reddick.

Auditing Committee. We, the undersigned Auditing Committee, have examined the books of the American Phytopathological Society, American Journal of Phytopathology, and the Lyman Endowment Fund. The books are found in good order with receipts and expenditures as stated by the Secretary-Treasurer, Mr. F. C. Meier.

R. E. VAUGHAN and J. B. KENDRICK.

De Bary Memorial Program Committee. A committee consisting of Mel T. Cook, F. M. Blodgett, and L. E. Melchers brought in the following report, which was adopted by the Society:

Your Committee on the de Bary Memorial Program for the next meeting recommends:

1. That the American Phytopathological Society invite the Mycological Section of the Botanical Society of America to join in a one-session program to be known as the de Bary Memorial Program.

2. That the secretaries of these two organizations be authorized to arrange said program.

3. That so far as possible the papers for said program be on subjects along the lines of de Bary's work. These papers may be selected from the papers submitted or by invitation, as may appear most satisfactory to the secretaries.

MEL T. COOK, *Chairman,*
F. M. BLODGETT,
L. E. MELCHERS.

Resolutions Committee. A committee consisting of H. W. Anderson, R. P. White, and J. G. Leach brought in the following resolutions, all of which were adopted.

Resolved: That the American Phytopathological Society, assembled at Des Moines, Iowa, instruct its Secretary to extend to the newly formed Canadian Phytopathological Society, on behalf of its members, its congratulations upon the organization of the Society and its heartiest felicitations for continued growth and prosperity.

Resolved: That the members of the American Phytopathological Society hereby extend their sincere thanks to Dr. I. E. Melhus and other members of the Local Arrangements Committee for their efficient efforts contributing to the success of the 1929 convention of the Society held at Des Moines, and Ames, Iowa.

Resolved: That the American Phytopathological Society express its appreciation to the Des Moines Chamber of Commerce, through its Secretary, Mr. George Hamilton, for its generous help and cooperation during the preparation for and the holding of its 1929 annual meeting.

Resolved: That the Society express its appreciation to the Grant Club of Des Moines for the hospitality extended to the Society at its annual 1929 convention.

Resolved: That the Society express its appreciation of the facilities and assistance rendered by the public schools and Boy Scout organization of Des Moines during its annual convention.

Whereas: It has been called to our attention that Prof. W. J. Morse, of the Maine Agricultural Experiment Station, long an active and devoted member

of our Society, is at present seriously ill, *Be It Resolved*, that the Secretary be instructed to extend to him the sympathy of the Society and its hope for his early recovery.

ACTION OF THE COUNCIL

In addition to making the appointments mentioned in the first part of this report, the Council made the following recommendations, which were approved by the Society.

1. That inasmuch as a change in the Constitution would be necessitated, no special class of membership for commercial companies be recommended at this time.

2. That the invitaton of H. W. Anderson and M. W. Gardner for a summer field meeting in southern Illinois and Indiana be accepted and that a committee consisting of M. W. Gardner, H. W. Anderson, and Leslie Pierce be appointed to take charge of arrangements. (Owing to extensive damage from winter injury to fruit trees in these States, this meeting has since been canceled.)

3. That the Editor of PHYTOPATHOLOGY be allowed actual expenses for 1930 up to or within $300 for secretarial and editorial assistance. This is the same amount as last year.

4. That a committee be appointed to consider plans for the Chicago Exhibition of 1933, and, if thought desirable to enter such an exhibit, to bring in a plan at the beginning of the next annual meeting.

OTHER BUSINESS

The reports of officers, committees, and representatives, as printed above, were accepted.

The revised copy of the Constitution and By-Laws was ordered printed in PHYTOPATHOLOGY. The matter of printing a revised list of members was referred to the Council with power to act.

The Secretary read letters from T. G. Major notifying the members of the dissolution of the Canadian Division of the American Phytopathological Society and the organization of the Canadian Phytopathological Society. It was moved and carried that the Resolutions Committee draft a reply to the Canadian organization expressing our best wishes to the new organization.

B. M. Duggar announced that "Fifty Years of Phytopathology" (illustrated) by Erwin F. Smith, an invitation address before the International Congress of Plant Sciences, Ithaca, New York, August 20, 1926, is now available and may be obtained at 75 cents per copy by addressing him, University of Wisconsin, Madison, Wis.

Attention was called to the fact that the publication "Fungi of Iowa," by Gilman and Archer, may be purchased from the Business Manager of the Iowa State Journal of Science at $1.00 per copy.

A. H. R. Buller announced that "Selecta Fungorum Carpologia," by Tulasne, has been translated from Latin to English by W. B. Grove, the author of the "British Rust Fungi," and that the translation, along with reproductions of the plates, is now being published by the Oxford Press.

E. C. Stakman, speaking in behalf of the Endowment Fund Committee, brought up the matter of the desirability of the phytopathologists availing themselves of the opportunity to obtain group rates and special service from steamship companies for travel to the Botanical Congress and he pointed out that the Endowment Fund might well benefit from this arrangement, which means the equivalent of one free ticket for every twenty-five purchased. Following a discussion of this matter, G. H. Coons made a motion, which was carried, that some member of the Society be appointed as corre-

sponding agent of the U. S. Lines in order that the Endowment Fund might benefit and the individual members secure the special service offered to groups buying tickets. It was moved by E. L. Nixon and carried that G. K. K. Link,[1] of the University of Chicago be made sole correspondent in this matter.

It was moved by Donald Reddick and carried that, with the probability of an International Union being effected at the Botanical Congress in Cambridge, the matter of delegates be referred to the Council for action at the next meeting with a view to determining a permanent plan for financing delegates to the International Union if one be founded.

It was moved by Donald Reddick and carried that, in view of the fact that our new President is now to appoint committees, and with them one to go to Cambridge, and is abroad and therefore inaccessible, Dr. Haskell, retiring President, be made Chairman of the Committee on International Relations and that he select the other members of that committee. (The committee was reappointed with R. J. Haskell as Chairman.)

[1] Doctor Link is now actively carrying on this work, is in close touch with the steamship company, and inquiries should be addressed to him.

FRANKLIN SUMNER EARLE

SEPTEMBER 4, 1856—JANUARY 31, 1929

Franklin Sumner Earle took special courses at the University of Illinois and in 1902 received the degree of M.S. from the Alabama Polytechnic Institute.

In 1886 he was an assistant to Doctor Burrill in the Department of Botany of the University of Illinois; from 1894 to 1895 he was connected with the Mississippi Agricultural Experiment Station. In 1895–96 he was Assistant Pathologist in charge of the Mycological Herbarium of the U. S. Department of Agriculture. In 1896 he was Horticulturist at the Alabama Agricultural Experiment Station; in 1896–1901, Professor of Biology at the Alabama Polytechnic Institute; 1902–3, Assistant Curator in charge, Mycological Collections, New York Botanical Garden; 1904–6 Director, Estacion Central Agronomica of Cuba; 1908–11, Consulting Agriculturist to the Cuban-American Sugar Company; 1911–14, President, Cuba Fruit Exchange; 1918, studied sugar-cane mosaic in Porto Rico for the U. S. Department of Agriculture; 1922–23, Consulting Agriculturist to the Central Aguirre Sugar Company, Porto Rico. From 1924 until his death he had charge of the study of sugar-cane varieties for the Tropical Plant Research Foundation in Cuba.

He was a man of sterling character and friendly disposition, a devoted husband and father, greatly respected by his business and professional associates and acquaintances, and beloved by his more intimate colleagues and friends.

CHARLES W. DE REKOWSKI

SEPTEMBER 8, 1865—APRIL 16, 1929

Charles W. de Rekowski received his education in the Gymnasium and the University of Jena, Germany, where he specialized in agriculture. In 1866 he came to the United States where he became interested in the sugar-beet industry and was active and well known in that industry throughout the balance of his life. He was a member of a number of scientific societies and social clubs in different parts of the United States and was highly thought of by his many friends.

LEIGH H. PENNINGTON

OCTOBER 26, 1877—APRIL 24, 1929

Leigh H. Pennington received the degree of Bachelor of Arts from the University of Michigan in 1907 and the degree of Doctor of Philosophy from the same institution in 1909, specializing in botany and chemistry.

During the school year 1906–1907, he served as undergraduate assistant in botany at the University of Michigan and continued in the same position during his graduate study at the same institution, from 1907 to 1909. From 1909 to 1910, he was Instructor in Botany at Northwestern University. From 1910 to 1912, he was Assistant Professor at New York State College of Forestry. From 1912 to 1914, he was Associate Professor at the same institution and from 1914 to the time of his death, he was Professor of Forest Pathology in the same institution. During the summers of 1911 and 1912, he served as expert in the Office of Forest Pathology, U. S. Department of Agriculture, and at various intervals during 1917–1923, he served as pathologist or collaborator in the same office. During the summers of 1923, 1925, 1926, 1927, 1928 and at the time of his death, he served in the capacity of forest pathologist in the Office of Blister-Rust Control, U. S. Department of Agriculture, working on special phases of the white-pine blister-rust problem.

He was the author of numerous papers, chiefly in the field of forest pathology. He was a very able, far-seeing investigator, capable teacher, and willing cooperator, combining, in all, thoroughness and a very pleasing personality. Truly it may be said of him that "To Be of Service" was his watchword.

WILLIAM HARMON WRIGHT

JULY 8, 1885—MAY 3, 1929

William Harmon Wright graduated from Purdue University in 1908 and married Edna Fisher June 11 of the same year. He came to the University of Wisconsin that fall and received his Master's degree in 1909. His graduate work at Wisconsin was supplemented by a year at Cornell University, 1915–1916. The degree of Ph.D. was awarded him by the University of Wisconsin in 1924.

Professor Wright joined the staff of the University of Wisconsin as an assistant in Agricultural Bacteriology. He was successively promoted through the various ranks, occupying at the time of his death the position of Associate Professor of Agricultural Bacteriology.

He was an exceptional teacher. A thorough mastery of his subject and a delightful personality, activated by a glowing enthusiasm, enabled him to inspire, not only a large number of students, who came under his direction during his twenty years of service, but also those who were associated with him in his work. Although he had only a limited time for research, his zeal for original investigations and the fundamental work he accomplished were exceptional.